INCH-POUND

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MILITARY HANDBOOK

LOADS

AMSC N/A

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ABSTRACT

This handbook provides basic criteria for the estimation of loadings to be used in the design of civil engineering structures. It is intended for use by experienced architects and engineers. The contents include criteria relating to combining loads for purposes of design and suggested limitations on deflections.

FOREWORD

This handbook has been developed from an evaluation of facilities in the shore establishment, from surveys of the availability of new materials and construction methods, and from selection of the best design practices of the Naval Facilities Engineering Command (NAVFACENGCOM), other Government agencies, and the private sector. This handbook uses, to the maximum extent feasible, national professional society, association, and institute standards.

Do not deviate from this handbook without prior approval of NAVFACENGCOM Code 15C. Recommendations for improvement are encouraged from within the Navy and from the private sector and should be furnished on the DD Form 1426 provided inside the back cover to Officer in Charge, Naval Facilities Engineering Service Center, East Coast Detachment, Mr. Robert Prince, Code 00CE, 901 M Street, Building 218, Washington, DC 20374-6018, telephone commercial (202) 433-8761.

THIS HANDBOOK SHALL NOT BE USED AS A REFERENCE DOCUMENT FOR PROCUREMENT OF FACILITIES CONSTRUCTION. IT IS TO BE USED IN THE PURCHASE OF FACILITIES ENGINEERING STUDIES AND DESIGN (FINAL PLANS, SPECIFICATIONS, AND COST ESTIMATES). DO NOT REFERENCE IT IN MILITARY OR FEDERAL SPECIFICATIONS OR OTHER PROCUREMENT DOCUMENTS.

STRUCTURAL ENGINEERING CRITERIA MANUALS

Criteria Manual	Title	P/A
MIL-HDBK-1002/1	Structural Engineering General Requirements	NAVFAC
MIL-HDBK-1002/2	Loads	NAVFAC
MIL-HDBK-1002/3	Steel Structures	NORTHDIV
DM-2.04	Concrete Structures	LANTDIV
MIL-HDBK-1002/5	Timber Structures	NORTHDIV
MIL-HDBK-1002/6	Aluminum Structures, Masonry Structures, Composite Structures, and Other Structural Materials	NORTHDIV
DM-2.08	Blast Resistant Structures	NORTHDIV
DM-2.09	Masonry Structural Design for Tri-Service, TM-5-809-3, AFM 88-3, Chap 3	ARMY

NOTE: Design manuals, when revised, will be converted to military handbooks.

NOTICE OF
CHANGE

MIL-HDBK-1002/2A
NOTICE 1
5 June 1997

MILITARY HANDBOOK

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1. THE FOLLOWING PAGES OF MIL-HDBK-1002/2A HAVE BEEN REVISED AND SUPERSEDE THE PAGES LISTED:

NEW PAGE	DATE	SUPERSEDED PAGE	DATE
105	15 October 1996	No Change	
106	5 June 1997	106	15 October 1996
106a	5 June 1997	New Page	
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116	5 June 1997	116	15 October 1996
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2. RETAIN THIS NOTICE AND INSERT BEFORE TABLE OF CONTENTS.

3. Holders of MIL-HDBK-1002/2A will verify that page changes and additions indicated above have been entered. This notice page will be retained as a check sheet. This issuance, together with appended pages, is a separate publication. Each notice is to be retained by stocking points until the military handbook is completely revised or canceled.

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Section 1: INTRODUCTION

1.1 Scope. This handbook prescribes criteria for estimating loadings used in the design of civil engineering structures, including temporary and prefabricated structures. This handbook is not complete in itself; special loadings and special design criteria relating to specific types of structures (waterfront structures and airport pavements, for example) are presented in the various topical manuals and military handbooks which are a part of this series. Consult these manuals and handbooks where applicable.

1.2 Cancellation. This handbook, MIL-HDBK-1002/2A, dated 15 October 1996, cancels and supersedes MIL-HDBK-1002/2, dated September 1988.

Section 2: DEAD LOADS

2.1 Definition. The term "dead load" refers to the weights of integral materials and equipment (including the structure's own weight) supported in, or on, a structure and intended to remain permanently in place.

2.2 Unit Weights. Table 1 provides unit weights of various construction materials. Table 2 provides minimum design dead loads for assembled construction elements.

2.3 Allowance for Partitions. The weights of partitions are considered to be dead load. Provide for actual weights of partitions, as shown on the architectural plans for a building in the design.

2.3.1 Uniform Load Equivalents. The uniform load equivalents listed below may be used in lieu of actual partition weights, except in the following cases: (1) bearing partitions; (2) in toilet room areas (other than in one- and two-family residences); (3) in stair, elevator, and similar core areas; or (4) in areas where partitions are concentrated.

Partition Weight (plf) [N/m]	Equivalent Uniform Load (psf) [kPa] To be added to floor dead and live loads)
50 [730] or less	0 [0]
51 to 100 [740 to 1460]	6 [.29]
101 to 200 [1470 to 2920]	12 [.57]
201 to 350 [2930 to 5110]	20 [.96]
Greater than 350 [5110]	Use actual concentrated live loads.

In office or public buildings, or in other occupancies where partitions are likely to be subject to rearrangement or alteration, the minimum allowance for the weight of partitions shall be a uniform load equivalent of 20 pounds per square foot (psf) [.96 kPa].

2.3.2 Nonconcurrence. Design live loads may be omitted from the strip of floor area under each partition.

2.4 Service Equipment. Include in the dead load the weights of building service equipment, including: plumbing, stacks, piping, heating and air conditioning equipment, electrical equipment, elevators, elevator machinery, flues, and similar fixed equipment. Consider the weight of equipment that is part of the tenant occupancy of a given area as live load.

2.5 Soil and Soil Moisture. Unless test data is available to indicate otherwise, the unit weight of dry soil shall be 110 pounds per cubic foot (pcf) [1800 kg/cu. m], and the unit weight of saturated soil shall be 135 pcf [2200 kg/cu. m].

Table 1
Unit Weights

Material	pcf*	Material	pcf*
Metals, alloys, ores:		Hemlock	29
Aluminum, cast, hammered	165	Hickory	49
Brass, cast, rolled	534	Locust	46
Bronze, 7.9 to 14% Sn	509	Maple, hard	43
Bronze, aluminum	481	Maple, white	33
Copper, cast, rolled	556	Oak, chestnut	54
Copper ore, pyrites	262	Oak, live	59
Gold, cast, hammered	1205	Oak, red, black	41
Gold, bars, stacked	1133	Oak, white	46
Gold, coin in bags	1084	Pine, Oregon	32
Iron, cast, pig	450	Pine, red	30
Iron, wrought	485	Pine, white	26
Iron, spiegeleisen	468	Pine, yellow, long-leaf	44
Iron, ferrosilicon	437	Pine, yellow, short-leaf	38
Iron ore, hematite	325	Poplar	30
Iron ore, hematite in bank	160-180	Redwood, California	26
Iron ore, hematite loose	130-160	Spruce, white, black	27
Iron ore, limonite	237	Walnut, black	38
Iron ore, magnetite	315	Walnut, white	26
Iron slag	172	Masonry:	
Lead	710	Cast-stone masonry	
Lead ore, galena	465	(cement, stone, sand)	144
Magnesium, alloys	112	Cinder fill	57
Manganese	475	Concrete plain:	
Manganese ore, pyrolusite	259	Cinder	108

*Multiply values in "pcf" by 16.02 to get "kg/cu. m"

Table 1 (Continued)
Unit Weights

Material	pcf*	Material	pcf*
Mercury	849	gypsum, loose	53-64
Monel metal	556	gypsum, set	110
		bank slag	67-72
Nickel	565	Slags, bank screenings	98-117
Platinum, cast, hammered	1330	machine slag	96
Silver, cast, hammered	656	slag sand	49-55
Silver bars, stacked	590	Terra cotta, architectural:	
		filled	120
Silver coin in bags	590	unfilled	72
Steel, cast or rolled	490	Soil:	
Tin, cast, hammered	459	par. 2.5	
Tin ore, cassiterite	418	Minerals:	
Zinc, cast, rolled	440	Asbestos	153
Zinc ore, blende	253	Barytes	281
		Basalt	184
Timber, U.S. seasoned:		Slag	138
Moisture content by weight:		Stone (including gravel)	150
(Seasoned timber, 15 to 20%		Ashlar masonry:	
green timber, up to 50%)		Granite, syenite, gneiss	185
Ash, white, red	40	Limestone, marble	160
Cedar, white, red	22	Sandstone, bluestone	140
Chestnut	41	Mortar rubble masonry:	
Cypress	30	Granite, syenite, gneiss	155
Elm white	45	Limestone, marble	150
Fir, Douglas	32	Sandstone, bluestone	130
Fir, eastern	25	Dry rubble masonry:	
Sandstone, bluestone	110	Granite, syenite, gneiss	130
Brick masonry:		Limestone, marble	125
brick	140	Stone, quarried, filled:	
Common brick	120	Basalt, granite, gneiss	96
Concrete masonry:		Limestone, marble, quartz	95
Cement, stone, sand	144	Sandstone	82
Cement, slag, etc.	130	Shale	92
cinder, etc.	100	Greenstone, hornblende	107
Various building materials:		Bituminous substances:	
cinders	40-45	Asphaltum	81
portland, cement, loose	90	Coal, anthracite	97
portland, cement, set	183	Coal, bituminous	84

*Multiply values in "pcf" by 157.1 to get "N/cu. m"

Table 1 (Continued)
Unit Weights

Material	pcf*	Material	pcf*
Coal, lignite	78	Saltpeter	67
Coal, peat, turf, dry	47	Starch	96
Coal, charcoal, pine	23	Sulfur	125
Coal, charcoal, oak	33	Wool	82
Coal, coke	75	Various liquids:	
Graphite	131	Alcohol 100%	49
Paraffin	56	Acid, muriatic, 40%	75
Petroleum	54	Acid, nitric, 91%	94
Petroleum, refined	50	Acid, sulfuric, 87%	112
Petroleum, benzine	46	Coal, coke	23-32
Petroleum, gasoline	42	Various solids:	
Pitch	69	Cereals, oats-bulk	32
Tar, bituminous	75	Cereals, barley-bulk	39
Coal and coke, piled:		Cereals, corn, rye-bulk	48
Coal, anthracite	47-58	Cereals, wheat-bulk	48
Coal, bituminous, lignite	40-54	Cork, compressed	14.4
Coal, peat, turf	20-26	Cotton, flax, hemp	93
Coal, charcoal	10-14	Fats	58
Bauxite	159	Flour, loose	28
Borax	109	Flour, pressed	47
Chalk	137	Glass, common	156
Clay, marl	137	Glass, plate or crown	161
Dolomite	181	Glass, plate or crown	161
Feldspar, orthoclase	159	Glass, crystal	184
Gneiss, serpentine	159	Hay and straw - bales	20
Granite, syenite	175	Leather	59
Greenstone, trap	187	Paper	58
Gypsum, alabaster	159	Potatoes, piled	42
Hornblende	187	Rubber, caoutchouc	59
Limestone, marble	165	Rubber goods	94
Magnesite	187	Lye, soda, 66%	106
Phosphate rock, apatite	200	Oil, vegetable	58
Porphyry	172	Oil, creosote	65
Pumice, natural	40	Oil, fuel	60.6
Quartz, flint	165	Oil, gasoline	46
Sandstone, bluestone	147	Water, 4 C, max density	62.428
Shale, slate	175	Water, sea water	64
Soapstone, talc	169	Water, ice	56
Salt, granulated, piled	48	Water, snow, fresh fallen	8

*Multiply values in "pcf" by 157.1 to get "N/cu. m"

Table 2
Minimum Design Dead Loads for Assembled Elements of Construction

WALLS[1,3]	psf[2]
4-inch clay brick, high absorption	34
4-inch clay brick, medium absorption	39
4-inch clay brick, low absorption	46
4-inch sand-lime brick	38
4-inch concrete brick, heavy aggregate	46
4-inch concrete brick, light aggregate	33
8-inch clay brick, high absorption	69
8-inch clay brick, medium absorption	79
8-inch clay brick, low absorption	89
8-inch sand-lime brick	74
8-inch concrete brick, heavy aggregate	89
8-inch concrete brick, light aggregate	68
12-1/2-inch clay brick, high absorption	100
12-1/2-inch clay brick, medium absorption	115
12-1/2-inch clay brick, low absorption	130
12-1/2-inch sand-lime brick	105
12-1/2-inch concrete brick, heavy aggregate	130
12-1/2-inch concrete brick, light aggregate	98
17-inch clay brick, high absorption	134
17-inch clay brick, medium absorption	155
17-inch clay brick,	173
17-inch concrete brick, heavy aggregate	174
17-inch concrete brick light aggregate	130
22-inch clay brick, high absorption	168
22-inch clay brick, medium absorption	194
22-inch clay brick, low absorption	216
22-inch sand-lime brick	173
22-inch concrete brick, heavy aggregate	216
22-inch concrete brick, light aggregate	160
4-inch brick, 4-inch load-bearing structural clay tile backing	60
4-inch brick, 8-inch load-bearing structural clay tile backing	75
4-inch brick, 8-inch load-bearing structural clay tile backing	75
8-inch load-bearing structural clay tile	42
12-inch load-bearing structural clay tile	58
4-inch concrete block, heavy aggregate	30
8-inch concrete block, heavy aggregate	55
12-inch concrete block, heavy aggregate	85
4-inch concrete block, light aggregate	20
8-inch concrete block, light aggregate	35
12-inch concrete block, light aggregate	55
2-inch furring tile, one side	12

[1,2,3]See footnotes at end of table.

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

PARTITIONS[1,3]	psf[2]	PARTITIONS[1,3]	psf[2]
3-inch clay tile	17	Wood studs, 2 x 4:	
4-inch clay tile	18	12-inch o.c.	2.1
6-inch clay tile	28	16-inch o.c.	1.7
8-inch clay tile	34	24-inch o.c.	1.3
10-inch clay tile	40	Wood studs, 2 x 4,	12
2-inch facing tile	15	plastered one side	
4-inch facing tile	25	Wood studs, 2 x 4,	20
6-inch facing tile	38	plastered two sides	
2-inch gypsum block	9-1/2	Steel or wood studs,	6
3-inch gypsum block	10-1/2	5/8-inch gypsum board each side	
4-inch gypsum block	12-1/2	Steel or wood studs,	9
5-inch gypsum block	14	2 layers 2-inch gypsum board	
6-inch gypsum block	18	each side	
2-inch solid plaster	20	Glass block masonry:	
4-inch solid plaster	32	4-inch glass-block walls	18
4-inch hollow plaster	22	and partitions	
4-inch concrete block,	30	Steel partitions	4
heavy aggregate		Asbestos hard board	
		(corrugated),	3
6-inch concrete block,	42	per 1/4-inch of thickness	
heavy aggregate		Stone, 4-inch	55
8-inch concrete block,	55	Split furring tile:	
heavy aggregate		1-1/2-inch	8
12-inch concrete block,	85	2-inch	8-1/2
heavy aggregate		Concrete slabs:	
4-inch concrete block,	20	Concrete, reinforced-stone,	12-1/2
light aggregate		per inch of thickness	
6-inch concrete block,	28	Concrete, reinforced-cinder,	9-1/2
light aggregate		per inch of thickness	
8-inch concrete block,	38	Concrete, reinforced,	
light aggregate		lightweight, per inch of	
		thickness	9
12-inch concrete block,	55	Concrete, plain, lightweight	12
light aggregate		per inch of thickness	
		Concrete, plain cinder,	9
		per inch of thickness	

[1,2,3]See footnotes at end of table.

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

Ribbed Slabs							
Depth in inches (rib depth ± slab thickness)[3]	Width of rib in inches[3]						Add for tapered ends
	psf[2]						
	4	5	6	7	8	9	
20-inch metal fillers:							
6 plus 2 1/2	45	48	50	50	-	-	4
8 plus 2 1/2	51	54	57	60	-	-	5
10 plus 2 1/2	57	60	64	68	-	-	5
12 plus 2 1/2	63	67	72	76	-	-	5
14 plus 2 1/2	-	74	79	84	-	-	5
16 plus 2 1/2	-	-	88	93	98	-	
20 plus 2 1/2	-	-	-	111	118	-	
30-inch metal fillers:							
6 plus 2 1/2	41	43	45	47	-	-	3
8 plus 2 1/2	45	47	50	53	-	-	4
10 plus 2 1/2	49	52	55	58	-	-	4
12 plus 2 1/2	53	57	60	64	-	-	4
14 plus 2 1/2	-	62	66	70	-	-	4
16 plus 2 1/2	-	-	72	76	80	-	
20 plus 2 1/2	-	-	-	90	95	101	
2-way clay tile fillers: (12x12):							
4 plus 2	61	62	64	-			-

Ribbed Slabs						
Depth in inches (rib depth ± slab thickness)[3]	Width of rib in inches[3]					Add for tapered ends
	psf[2]					
	4	5	6	7	8	
6 plus 2	87	89	90	-		-
8 plus 2 1/2	100	103	107	-		-
10 plus 3	121	126	131	-		-
12 plus 3	136	141	146	-		-
2-way metal fillers: (16x16):						
4 plus 2	44	47	50	-		-
6 plus 2	55	60	63	-		-
8 plus 2 1/2	72	78	83	-		-
10 plus 3	91	96	103	-		-
12 plus 3	103	111	118	-		-
14 plus 3	116	125	133	-		-
2-way metal fillers: (20x20):						
4 plus 2	42	44	46	-		-
6 plus 2	50	54	58	-		-
8 plus 2 1/2	66	71	76	-		-
10 plus 3	83	88	94	-		-
12 plus 3	93	100	107	-		-
14 plus 3	105	113	120	-		-

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

Ribbed Slabs

Depth in inches (rib depth ± slab thickness)[3]	Width of rib in inches[3], psf[2]: 4	5	6	7	8	Add for tapered ends
12-inch clay file filters:						
4 plus 2	49	51	52	54		-
6 plus 2	60	63	65	67		-
8 plus 2 1/2	79	82	85	87		-
10 plus 3	96	100	103	106		-
12 plus 3	108	112	116	120		-

WAFFLE SLABS Depth, in Inches (Rib Depth + Slab Thickness)[3]	Load psf[2]
19 x 19, 5 @ 24	
6 plus 2 1/2	64
8 plus 2 1/2	70
10 plus 2 1/2	85
12 plus 2 1/2	101
30 x 30, 6 @ 36	
8 plus 3	73
10 plus 3	83
12 plus 3	95
14 plus 3	106
16 plus 3	114
20 plus 3	135

Floor finish[3]	Thickness in.[3]	Load psf[2]
1 1/2-inch asphalt mastic flooring	1 1/2	18
3-inch wood block on 1/2-inch mortar base	3 1/2	16
Solid flat tile on 1-inch mortar base	2	23
2-inch asphalt block, 1/2-inch mortar	2 1/2	30
1-inch terrazzo, 2-inch stone concrete	3	38
7/8-inch hardwood floor on sleepers clipped to concrete without fill	-	5
3/4-inch ceramic or quarry tile on 2-inch mortar bed	1 1/4	16
3/4-inch ceramic or quarry tile on 1-inch mortar bed	2 3/4	34
1/4-inch linoleum or asphalt tile directly on concrete	-	1
1/4-inch linoleum or asphalt tile on 1-inch mortar bed	1 1/4	12
Hardwood floor, 7/8-inch thick	7/8	4
Subflooring (soft wood)	3/4	2 1/2
Waterproofing:		
Five-ply membrane	1/2	5
Five-ply membrane, mortar, stone concrete	5	55
2-inch split tile, 3-inch stone concrete	5	45

[2,3]See footnotes at end of table.

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

Floor finish[3]	Thickness in.[3]	Load, psf[2]
Floor fill:		
Cinder concrete, per inch	-	9
Lightweight concrete, per inch	-	7
Sand, per inch	-	8
Stone concrete, per inch	-	12
Wood joist floors (no plaster) double wood floor[3]	**12-inch spacing, psf[2]**	**16-inch spacing, psf[2]**
Joist sizes, in inches:		
2 x 6	6	5
2 x 8	6	6
2 x 10	7	6
2 x 12	8	7
3 x 6	7	6
3 x 3	8	7
3 x 10	9	8
3 x 12	11	9
3 x 14	12	10

Ceilings[3]	psf[2]
Plaster on tile or concrete	5
Suspended metal lath and gypsum plaster	10
Suspended metal lath and cement plaster	15
Plaster on wood or metal lath	8
1/2-inch gypsum board	2
5/8-inch gypsum board	2.5

Ceilings[3]	psf[2]
Acoustical fiber tile directly on concrete blocks or tile	1
Acoustical fiber tile on lath and channel ceiling construction	5
Acoustical fiber tile on suspended wood furring strips	3
Roof and wall coverings:	**psf[2]**
Clay tile (for mortar add 10 lb [45 N])	
2-inch book tile	12
3-inch book tile	20
Roman	12
Spanish	19
Ludovici	10
Composition	
Three-ply ready roofing	1
Four-ply felt and gravel	5.5
Five-ply felt and gravel	6
Cold applied sheet membrane and stone ballast	see mfr.
Copper or tin	1
Corrugated asbestos-cement roofing	4
Corrugated iron	2
Decking (non wood) per inch of thickness:	
Concrete plank	6.5
Insulrock	2.7
Poured gypsum	6.5
Tectum	2.0
Vermiculite concrete	2.6
Fiberboard 1/2-inch	.75
Glass	
Windows, glass, frame, and sash	8

[2,3]See footnotes at end of table.

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

Roof and wall coverings[3]	psf[2]
Single strength	1.2
Double strength	1.6
Plate, wired or structural, 1/8-inch	1.4
Insulating, double 1/8-inch plates w/air space	3.5
Insulating, double 1/4-inch plates w/air space	7.1
Gypsum sheathing, 1/2-inch	2.0
Insulation, per inch of thickness	
Expanded polystyrene	0.2
Fiber glass, rigid	1.5
Foam glass	0.8
Loose	0.5
Urethane	1.0
Cork	1.0
Vegetable fiber boards	1.5
[illegible] and blankets	0.5
Rigid insulation board	2.5
Insulating concrete	3.0
Marble, interior, per inch	14.0
Metal deck (22 gauge)	1.9
Metal deck (20 gauge)	2.25
Metal deck (18 gauge)	3.0
Corrugated metal (20 gauge)	1.5
Plastic, acrylic, 1/4 inch	1.5
Porcelain enamel on sheet ste·	3.0
Skylight, metal frame, 3/8-inch wire glass	8.0
Slate, 3/16-inch	7.0
Slate, 1/4-inch	10.0
Stucco, 7/8-inch	10.0
Terra cotta tile	25.0
Wood sheathing, per inch thickness	3.0
Wood shingles	3.0
Asphalt shingles	2.0

Roof and wall coverings[3]	psf[2]
Cement asbestos shingles	4
Cement tile	16

Floor finish and fill[3]	Finish floor to top slab inches[3]	Load psf[2]
Linoleum on stone-concrete fill	4	46
Linoleum on stone-concrete fill	5	58
Linoleum on light-concrete fill	4	27
Linoleum on light-concrete fill	5	34
Double 7/8-inch wood on sleepers, light concrete fill	4	19
Double 7/8-inch wood on sleepers, light concrete fill	5	26
Double 7/8-inch wood on sleepers, stone-concrete fill	4	28
Double 7/8-inch wood on sleepers, stone-concrete fill	5	40
Single 7/8-inch wood on sleepers, light concrete fill	4	23
Single 7/8-inch wood on sleepers, light concrete fill	5	30
Single 7/8-inch wood on sleepers, stone-concrete fill	4	40
Single 7/8-inch wood on sleepers, stone-concrete fill	5	50
3-inch wood block on mastic, no fill	3	10

[2,3]See footnotes at end of table.

Table 2 (Continued)
Minimum Design Dead Loads for Assembled Elements of Construction

Floor finish and fill[3]	Finish floor to top slab inches[3]	Load, psf[2]
7/8-inch wood block on stone-concrete fill	4	40
1-inch cement finish on stone-concrete fill	4	48
1-inch terrazzo on stone-concrete fill	4	48
Clay tile on stone-concrete fill	4	48
Marble and mortar on stone-concrete fill	4	50
Hollow core planks	(2)	(2)

[1] For masonry construction, add 5 psf [.24 kPa] for each face plastered.
[2] Multiply values in "psf" by .04788 to get values in "kPa."
[3] Multiply values in "inches" by 25.4 to get values in "mm."
[4] See manufacturer's data for sizes and weights which are available locally.

2.6 Stability. For stability calculations (e.g., overturning, sliding, and rotation), decrease estimates of dead load by 10 percent (0.90 load factor indicated in par. 10.3), and discount the following elements of dead load:

a) Allowances for future addition or future wearing course;

b) Allowances for fills and finishes, where such fills and finishes are intended to be replaced periodically;

c) Weight of overlying soil. Provide the required safety factors identified in DM-7.01, Soil Mechanics, and DM-7.02, Foundations and Earth Structures, assuming full overlying soil in place. Additionally, provide a stability factor of 1.05, with the weight of the overlying soil discounted. These values apply under the design loads. Exception: for cases in which the weight (or passive resistance) of the soil will clearly be a design consideration in future excavations, lesser stability factors are permitted.

Section 3: LIVE LOADS (INCLUDING LIVE LOAD REDUCTION)

3.1 Definition. Live loads include all loads (vertically down, vertically up, and lateral) incident to the occupancy and use of a structure. Live loads exclude forces incident to the environment (e.g., snow, wind, rain, earthquake, stream flow, waves, ice, the impact of berthing, the weight and lateral pressure due to earth). Consider centrifugal traction, braking, and impact forces as incidental to (and a part of) the live load effect. For definitions of Class A, Class B, and Class C Structures, refer to MIL-HDBK-1002/1, Structural Engineering General Requirements.

3.2 Class A Structures. The provisions of the American Association of State Highway and Transportation Officials (AASHTO) and American Railway Engineering Association (AREA) design standards apply.

3.3 Class B Structures

3.3.1 Snow Load. Refer to Section 5.

3.3.2 Wind Load. Refer to Section 7.

3.3.3 Roof Loads

a) Concurrence. Concurrent with snow load, provide the design of roofs for loads incident to ponding of rainwater. Non-concurrent with snow load, provide for the loads incident to the weight of people, materials, and equipment necessary to make repairs during the service life of the roof. The weight of people, materials, and equipment necessary to make repairs during the service life of the roof also are considered as non-concurrent with the design wind load.

b) Ponding. Calculate the load due to ponding on the basis of the flexibility of the roof structure, an initial deviation from a plane or sloped surface of at least 1-1/2 inches [38 mm], and the adequacy of the drainage system (the provisions of MIL-HDBK-1002/1 notwithstanding, a storm of 50 year recurrence interval shall be considered).

c) Minimum Design Load. The purpose of a minimum design load is to provide for the weight of people, materials, and equipment.

Make allowance in the design of secondary framing (e.g., roof deck and rafters) for a minimum load of 15 psf [.72 kPa] for roof slopes of 1 vertical to 2 horizontal, or steeper; and 20 psf [.96 kPa] for flatter roofs; each coupled with a concentrated load of 250 pounds [1110 N] on a 24-inch [610 mm] by 24-inch [610 mm] area. For main members (e.g., trusses and arches) the minimum design load may be reduced to 12 psf [.57 kPa].

These provisions for minimum load do not apply if special scaffolding, runners, or similar device is provided as a work surface for workmen and materials during construction and repair operations.

3.3.4 Uniformly Distributed Loads. The live loads to be assumed in the design of Class B Structures are the maximum loads likely to be imposed by the intended use or occupancy, but not less than those indicated in Table 3.

3.3.5 Thrusts on Handrails. Design both exterior and interior stairway and balcony railings to resist a simultaneous vertical and horizontal thrust of 50 pounds per linear foot [730 N/mm] applied to the top rail. For one- and two-family dwellings, the thrusts shall be 20 pounds per linear foot [290 N/m].

3.3.6 Concentrated Loads

a) Consider application of a concentrated load in the design of a sidewalk. The concentrated load to be considered is the maximum wheel load which reasonably could mount the sidewalk, but applied without impact. Use this concentrated load in the design of appurtenant components of sidewalks (e.g., manholes, manhole covers, vault covers, and gratings).

b) Driveways shall be considered Class A Structures.

c) Accessible, open-web steel joists over garages or manufacturing spaces shall be capable of supporting an 800-pound [3560 N] concentrated load placed at any bottom chord panel point, applied concurrently with the other live loads. This load shall be considered a load of infrequent occurrence. Note that this requirement normally will require reinforcing the panel point connections of joists of standard design; this requirement should be stated on the construction plans.

Table 3
Uniform Live Load Requirements for Special Occupancy

OCCUPANCY OR USE	LIVE LOAD (psf)	[kPa]
Armories (see Drill Halls)		
Assembly area (including theaters)		
Fixed Seats (fastened to floor)	60	2.9
Movable seats	100	4.8
Lobbies	100	4.8
Platforms (assembly)	100	4.8
Stage floors	150	7.2
Automatic data processing rooms	150	7.2
Bag storage	125	6.0
Balconies, one- and two-family residences and not exceeding 100 sq. ft. [9.3 sq. m]	60	2.9
Balconies, other	100	4.8
Bakeries, general area	100	4.8
Bakeries, storage area	200	9.6
Barber shop	75	3.6
Barracks and dormitories		
partitioned	40	1.9
non-partitioned, including allowances for future partitions	60	2.9
corridors	100	4.8
Battery charging room	200	9.6
Boiler houses	200	9.6
Bowling alleys, poolrooms, and similar recreation areas	75	3.6
Car wash rooms	75	3.6
Canteens, general area	100	4.8
Canteens, storage area	200	9.6
Catwalks, buildings	25	1.2
Catwalks, Marine	50	2.4
Chapels		
Aisles, corridors, and lobbies	100	4.8
Balconies	60	2.9
Fixed seats	60	2.9
Offices and miscellaneous rooms	40	1.9
Cobbler shop	100	4.8
Computer rooms	100	4.8

Table 3 (Continued)
Uniform Live Load Requirements for Special Occupancy

OCCUPANCY OR USE	LIVE LOAD (psf)	[kPa]
Concentrated loads:		
Elevator machine room grating (on area of 4 sq. in. [2600 sq. mm])	300 lb.	1330 N
Finish light floor plate construction (on area of 1 sq. in. [650 sq. mm])	200 lb.	890 N
Main corridors, large offices, and similar areas (on 2.5 ft. x 2.5 ft. [760 mm x 760 mm])	2000 lb.	8900 N
Scuttles, skylight ribs, and accessible ceilings	200 lb.	890 N
Sidewalks (on 2.5 ft. x 2.5 ft. [760 mm x 760 mm])	8000 lb.	35 600 N
Stair treads (on center of tread)	300 lb.	1330 N
Court rooms	80	3.8
Dance halls and ballrooms	100	4.8
Day rooms	60	2.9
Dining rooms and restaurants	100	4.8
Kitchen, general area	75	3.6
Drawing	100	4.8
Drill halls	125	6.0
Drum fillings	150	7.2
Drum washing	75	3.6
File rooms:		
Letter files	80	3.8
Card files	125	6.0
Drawing files	200	9.6
Fire escapes (single-family dwellings)	40	1.9
Galleys:		
Dishwashing rooms (mechanical)	300	14
General kitchen area	75	3.6
Provision storage (not refrigerated)	200	9.6
Preparation room:		
meat	250	12
vegetable	100	4.8
Garages		
Passenger cars	50	2.4
Trucks and buses - see Class A Structures		
Garbage storage rooms	125	6.0
Generator rooms	200	9.6

Table 3 (Continued)
Uniform Live Load Requirements for Special Occupancy

OCCUPANCY OR USE	LIVE LOAD (psf)	[kPa]
Guard house	75	3.6
Gymnasiums (main floors and balconies)	100	4.8
Hangars (Obtain wheel loads of aircraft and impact factors from using agency.)		
Hospitals		
Operating rooms, laboratories	60	2.9
Private rooms	40	1.9
Wards	40	1.9
Corridors (above first floor)	80	3.8
Incinerators; charging floor	150	7.2
Laboratories; normal scientific equipment	100	4.8
Latrines	75	3.6
Laundries; general areas	100	4.8
Libraries		
Reading rooms	60	2.9
Stock rooms (books and shelving @ 65 pcf) [1040 kg/cu. m] but not less than	150	7.2
Corridors, above first floor	80	3.8
Linen storage	125	6.0
Lobbies, vestibules and large waiting rooms	100	4.8
Locker rooms	75	3.6
Lounges, day rooms, small recreation areas	60	2.9
Manufacturing		
Light	125	6.0
Heavy	250	12
Marquee and canopies	75	3.6
Mechanical equipment rooms (general)	100	4.8
Mechanical room (air conditioning)	125	6.0
Mechanical telephone and radio equipment rooms	150	7.2
Mess halls	100	4.8
Morgues	100	4.8
Office buildings		
Offices	50	2.4
Lobbies	100	4.8
File and computer rooms (to be individually evaluated)		

Table 3 (Continued)
Uniform Live Load Requirements for Special Occupancy

OCCUPANCY OR USE	LIVE LOAD (psf)	[kPa]
Post exchanges (see Stores)		
Post offices:		
General area	100	4.8
Work rooms	125	6.0
Power plants	200	9.6
Projection booths	100	4.8
Promenade roof	60	2.9
Pump houses	100	4.8
Recreation rooms	100	4.8
Receiving rooms (radio) including roof areas supporting antennas and electronic equipment	150	7.2
Refrigeration storage rooms:		
Dairy	200	9.6
Meat	250	12
Vegetables	275	13
Residential:		
One- and two-family dwellings:		
Uninhabitable attics without storage	10	.48
Uninhabitable attics with storage	20	.96
Habitable attics and sleeping areas	30	1.4
All other areas	40	1.9
Hotel and multi-family houses		
Private rooms and corridors serving them	40	1.9
Public rooms and corridors serving them	100	4.8
Rubbish storage rooms	100	4.8
Scrub decks	75	3.6
Shops:		
Aircraft utility	200	9.6
Assembly and repair	250 to 400	12 to 19
Blacksmith	125	6.0
Bombsight	125	6.0
Carpenter	125	6.0
Drum repair	100	4.8
Electrical	300	14
Engine overhaul	300	14

Table 3 (Continued)
Uniform Live Load Requirements for Special Occupancy

OCCUPANCY OR USE	LIVE LOAD (psf)	[kPa]
Store houses:		
Aircraft	200	9.6
Ammunition (one story)	2000	96
Cold storage:		
first floor	400	19
upper floors	300	14
Dry provisions	300	14
Fuse and detonator (one story)	500	24
General:		
first floor	600 to 1000	29 to 48
second floor	400	19
third floor	300	14
high explosives (one story)	500	24
inert materials (one story)	500 to 2000	24 to 96
light tools	150	7.2
paint and oil (one story)	500	24
pipe and metals (one story)	1000	48
pyrotechnics (one story)	500	24
small arms (one story)	500	24
subsistence buildings	200	9.6
torpedo (one story)	350	17
Stores (Sales)		
Retail		
First floor	100	4.8
Upper floors	75	3.6
Wholesale, all floors	125	6.0
Tailor shop	75	3.6
Telephone exchange rooms		
Normal	150	7.2
Locations subject to earth tremors, gunnery practice or other conditions causing unusual vibrations	250	12
Terminal equipment buildings (all areas other than stairs, toilets, and washrooms)	150	7.2
Walkways and elevated platforms (other than exitways)	60	2.9
Yards and terraces (pedestrian)	100	4.8

d) Any single panel point of the lower chord of accessible roof trusses (other than open-web joists), or any point of other accessible primary structural members over commercial garage, manufacturing and storage floors, and maintenance and repair facilities, shall be designed to support a 2000 pound [8900 N] concentrated load, applied concurrently with other live loads. This load shall be considered a load of infrequent occurrence.

e) For quarters, consider a concentrated load of 200 pounds [890 N] on an area of 4 square inches [2600 sq. mm].

f) The provisions of Table 3 relating to light floor plate construction apply to floor insets, such as registers.

g) For boiler rooms, make allowance for a 3000 pound [13 300 N] concentrated load applied over an area of 20 square inches [12 900 sq. mm], in areas outside the limits of the boilers, applied non-concurrently with the uniform live load.

h) Floors in garages or portions of buildings used for storage of motor vehicles shall be designed for the following concentrated loads: (1) for passenger cars accommodating not more than nine passengers, 2000 pounds [8900 N] acting on an area of 20 square inches [12 900 sq. mm]; (2) mechanical parking structures without slab or deck, for passenger cars only, 1500 pounds [6670 N] per wheel; and (3) for trucks or buses, maximum axle load on an area of 20 square inches [12 900 sq. mm].

3.3.7 Live Load Reduction

a) Subject to limitations indicated in par. 3.3.7b), members having an influence area of 400 square feet [37 sq. m] or more may be designed for a reduced live load determined by applying the following:

$$\text{Equation:} \quad L = L_o\left(0.25 + \frac{15}{\sqrt{A_I}}\right) \text{ In English Units} \quad (1)$$

$$[L = L_o(0.25 + 4.57/\sqrt{A_I})] \quad \text{In SI Units}$$

where: L = reduced design live load per square foot [square meter] of area supported by the member

L_o = unreduced design live load per square foot [square meter] of area supported by the member.

A_I = influence area, square feet [square meters]. The influence area, A_I, is four times the tributary area for a column, two times the tributary area for a beam, and is equal to the panel area for a two-way slab. (See Figure 1.)

b) Limitations on Live Load Reduction. The reduced design live load shall not be less than 50 percent of the basic live load (L_o) for members supporting one floor, nor less than 40 percent of L_o, otherwise.

c) Exceptions to permissible reductions. The following are exceptions to the reductions in subpars. a) and b) above.

(1) For live loads greater than 100 psf [4.8 kPa] and for garages used for passenger cars only, no reduction is permitted for members supporting one floor; however, where two or more floors are supported, a 20 percent reduction is permitted.

(2) For live loads less than 100 psf [4.8 kPa], no reduction is permitted for members supporting floor(s) in the following areas: public assembly; garages, except where two or more floors are supported as noted in Equation (1) above; one-way slab floor.

3.3.8 Live Loads for Warehouses. See Table 4.

3.4 Class C Structures. The provisions of the applicable criteria manual series shall apply.

3.5 Partial Loadings

3.5.1 Pattern Loadings. The provisions of American Concrete Institute (ACI)-318, Building Code Requirements for Reinforced Concrete, relating to frame analysis and design (arrangement for live load) apply.

3.5.2 Moving Loads. For structures subject to moving or to variable loads, design each part with those live loads on the structure that develop the maximum stresses in the considered part.

3.5.3 Unsymmetrical Loadings. Note that for a slender compression members, and for members which lack torsional rigidity, the torsions and eccentricities induced by unsymmetrical loadings may be more critical than the effects of heavier, symmetric loadings. Several collapses, particularly of light roof structures, have been attributed to this cause. Stresses in cantilever framing also are sensitive to partial, unsymmetrical loading.

3.5.4 Prestressing (Including Post-Tensioning) Forces. Consideration of partial tensioning, and increments of tensioning is required.

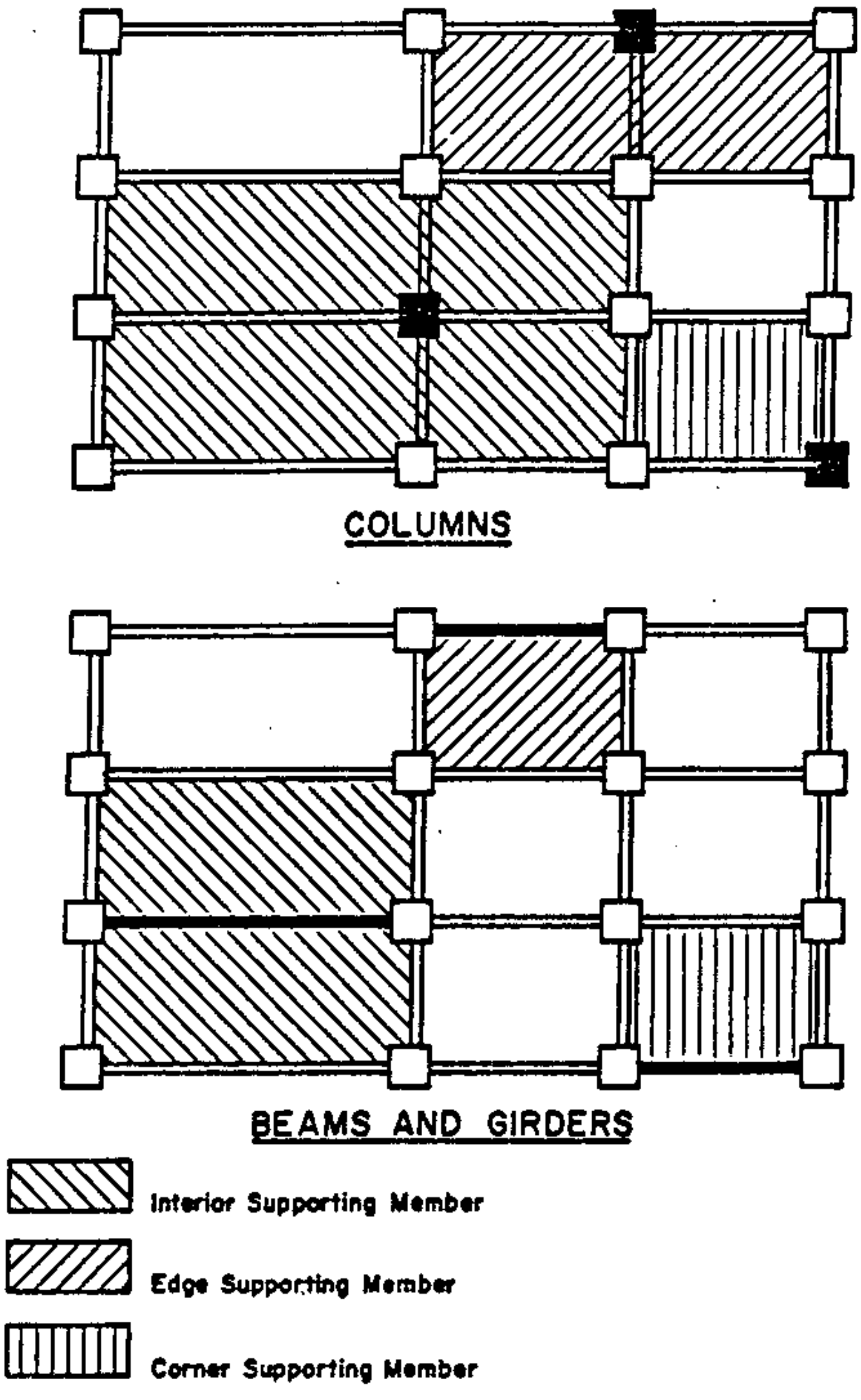


Figure 1
Typical Influence Areas

Table 4
Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb)[1]	Height of pile (ft)[2]	Weight per square foot of floor (lb)[1]	Live Load (psf)[3]
Building materials:				
Asbestos	50	6		300
Bricks, building	45	6		270
Bricks, fire clay	75	6		450
Cement, natural	59	6	354	300
Cement, portland	72 to 105	6	432 to 630	to
Gypsum	50	6	300	400
Lime and plaster	53	5	265	
Tiles	50	6	300	
Woods, bulk	45	6	270	
Drugs, paints, oil:				
Alum, pearl, in barrels	33	6	198	
Bleaching powder, in hogsheads	31	3-1/2	102	
Blue vitriol, in barrels	45	5	225	
Glycerine, in cases	52	6	312	
Linseed oil, in barrels	36	6	216	
Linseed oil, in iron drums	45	4	180	
Logwood extract, in boxes	70	5	350	
Rosin, in barrels	48	6	288	
Shellac, gum	38	6	228	200
Soaps	50	6	300	to
Soda ash, in hogsheads	62	2-3/4	167	300
Soda, caustic, in iron drums	88	3-3/8	294	
Soda, silicate, in barrels	53	6	318	
Sulfuric acid	60	1-5/8	100	
Toilet articles	35	6	210	
Varnishes	55	6	330	
White lead paste, in cans	174	3-1/2	610	
White lead, dry	86	4-3/4	408	
Red lead and litharge, dry	132	3-3/4	495	

[1,2,3] See footnotes at end of table.

Table 4 (Continued)
Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb) [1]	Height of pile (ft) [2]	Weight per square foot of floor (lb) [1]	Live Load (psf) [3]
Dry goods, cotton, wool:				
Burlap, in bales	43	6	258	
Carpets and rugs	30	6	180	
Coir yarn, in bales	33	8	264	
Cotton, in bales, American	30	8	240	
Cotton, in bales, foreign	40	8	320	
Cotton bleached goods, in cases	28	8	224	
Cotton flannel, in cases	12	8	96	
Cotton sheeting, in cases	23	8	184	
Cotton yarn, in cases	25	8	200	
Excelsior, compressed	19	8	152	200
Hemp, Italian, compressed	22	8	176	to
Hemp, Manila, compressed	30	8	240	250
Jute, compressed	41	8	328	
Linen damask, in cases	50	5	250	
Linen goods, in cases	30	8	240	
Linen towels, in cases	40	6	240	
Silk and silk good	45	8	360	
Sisal, compressed	21	8	168	
Tow, compressed	29	8	232	
Wool, in bales, compressed	48			
Wool, in bales, not compressed	13	8	104	
Wool, worsteds, in cases	27	8	216	
Groceries, wines, liquors:				
Beans, in bags	40	8	320	
Beverages	40	8	320	
Canned goods, in cases	58	6	348	

[1,2,3] See footnotes at end of table.

Table 4 (Continued)
Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb) [1]	Height of pile (ft) [2]	Weight per square foot of floor (lb) [1]	Live Load (psf) [3]
Groceries, wines, liquors (continued):				
Cereals	45	8	360	
Cocoa	35	8	280	
Coffee, roasted, in bags	33	8	264	
Coffee, green, in bags	39	8	312	
Dates, in cases	55	6	330	
Figs, in cases	74	5	370	
Flour, in barrels	40	5	200	250
Fruits, fresh	35	8	280	to
Meat and meat products	45	6	270	300
Milk, condensed	50	6	300	
Molasses, in barrels	48	5	240	
Rice, in bags	58	6	348	
Sal soda, in barrels	46	5	230	
Salt, in bags	70	5	350	
Soap powder, in cases	38	8	304	
Starch, in barrels	25	6	150	
Sugar, in barrels	43	5	215	
Sugar, in cases	51	6	306	
Tea, in chests	25	8	200	
Wines and liquors, in barrels	38	6	228	
Hardware:				
Automobile parts	40	8	320	
Chain	100	6	600	
Cutlery	45	8	360	

[1,2,3] See footnotes at end of table.

Table 4 (Continued)
Uniform Live Loads for Storage Warehouses

Material	Weight per cubic foot of space (lb) [1]	Height of pile (ft) [2]	Weight per square foot of floor (lb) [1]	Live Load (psf) [3]
Hardware (Continued):				
Door checks	45	6	270	
Electrical goods and machinery	40	8	320	
Hinges	64	6	384	
Locks, in cases, packed	31	6	186	
Machinery, light	20	8	160	
Plumbing fixtures	30	8	240	300
Plumbing supplies	55	6	330	to
Sash fasteners	48	6	288	400
Screws	101	6	606	
Shafting steel	125			
Sheet tin, in boxes	278	2	556	
Tools, small, metal	75	6	450	
Wire cables, on reels	-	-	425	
Wire, insulated copper, in coils	63	5	315	
Wire, galvanized iron, in coils	74	4-1/2	333	
Wire, magnet, on spools	75	6	450	
Miscellaneous:				
Automobile tires	30	6	180	
Automobiles, uncrated	8	-	64	
Books (solidly packed)	65	6	390	
Furniture	20	-		
Glass and chinaware, in crates	40	8	320	
Hides and leather, in bales	20	8	160	--
Leather and leather goods	40	8	320	
Paper, newspaper, & strawboards	35	6	210	
Paper, writing and calendared	60	6	360	
Rope, in coils	32	6	192	
Rubber, crude	50	8	400	
Tobacco, bales	35	8	280	

Notes: [1] Multiply values in "pounds" by 4.448 to get values in "N"
[2] Multiply values in "ft" by 304.8 to get values in "mm"
[3] Multiply values in "psf" by .04788 to get values in "kPa"

Section 4: IMPACT, TRACTION, AND SWAY

4.1 Class A Structures. Provisions of AASHTO and AREA standards apply.

4.2 Crane Runways and Supports - Impact. Provisions of Table 5 apply.

4.3 Crane Runways and Supports - Traction and Sway. Provisions of DM-38.01, Weight-Handling Equipment apply.

4.4 Machinery Supports

Type of Machinery	Minimum Impact Allowance
1. Reciprocating Machinery and Heavy Power-Driven Units	50% of weight of machine
2. Light, Shaft- or Motor-Driven Units	25% [1]
3. Elevator Machinery	Supporting Beams - 100% [2] Supporting Columns - 80% [2] Foundations - 40% [2]
4. Escalators	15% [3]

Notes: [1] of total weight of machine.
[2] of total lifted load, including live load.
[3] of weight of moving parts, plus live load.

4.5 Sway Load on Spectator Stands. Provide for a lateral load effect equal to 24 pounds per linear foot [350 N/m] of seating applied in a direction parallel to each row of seats, and 10 pounds per linear foot [150 N/m] of seating applied in a direction perpendicular to the row of seats. Apply these two components of sway load simultaneously. The sway load on spectator stands is considered to be concurrent with a wind load generated by a wind velocity equal to one-half the velocity of the design wind load, but not more than 50 miles per hour [22 m/sec].

4.6 Hangers for Floors and Balconies. Provide for impact equal to one-third of the tension due to the live load.

Table 5
Crane Runways and Supports, Load Increases for Impact

Capacity of hook load (short tons) [kN]	Load increase expressed as percent of maximum crane reaction							
	Speeds 200 fpm [1 m/sec] or less				Speeds exceeding 200 fpm [1 m/sec]			
	Overhead traveling crane, traveling wall crane		Fixed revolving cranes	Traveling revolving cranes	Overhead traveling crane, traveling wall crane		Fixed revolving cranes	Traveling revolving cranes
	Runway girders	Columns	Towers	Docks, piers, tracks	Runway girders	Columns		
25 or less [225 or less]	15	12	15	12	18	14	18	15
26 to 50 [225 to 445]	13	10	13	10	15	10	15	12
51 to 80 [446 to 710]	10	9	10	8	12	12	12	10
81 to 120 [711 to 1070]	9	7	9	6	10	8	10	8
121 to 180 [1071 to 1600]	8	6	8	6	9	7	9	8
Over 180 [over 1600]	6	5	6	6	8	6	8	8

4.7 Impact Due to Berthing. Refer to MIL-HDBK-1025/1, Piers and Wharves, for evaluation of lateral and longitudinal forces.

4.8 Vibrations. Vibrations are induced in structures by reciprocating and rotating equipment, rapid application and subsequent removal of a load, or by other means. Vibrations take place in flexural, extensional, or torsional modes, or any combination of the three.

4.8.1 Resonance. Resonance occurs when the frequency of an applied dynamic load coincides with a natural frequency of the supporting structure. In this condition, vibration deflections increase progressively to dangerous proportions. Prevent resonance by ensuring, in the design, that the natural frequency of a structure and the frequency of load application do not coincide.

4.8.2 Foundation Considerations. Foundations for vibratory machinery require careful consideration. Refer to NAVFAC DM-7.01, DM-7.02, and DM-7.03, Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction, for the reaction of different types of soils to vibratory loading and the determination of the natural frequency of the foundation-soil system.

4.8.2.1 Foundation Design. Select the geometry and mass of the foundation based on proper analysis satisfying imposed or appropriate restrictions on resulting foundation movements (lateral, vertical, and torsional). Consider foundation material properties and interaction with foundation. For analysis, select dynamic loads based on characteristics of machine operation (preferably measured or provided by manufacturer) and anticipated maintenance.

4.8.2.2 Isolation of Foundations for Vibrating Machinery. Foundations for heavy vibratory machinery are likely to require isolation from the surrounding structure, floors, and foundations. Depending on conditions, adequate isolation may be achieved by use of insulating pads or springs, or by leaving an open space between the machine base and surrounding structure. The latter method still requires evaluation of whether vibrations can be transmitted to the structure through the foundations. Refer to DM-7.01, DM-7.02, and DM-7.03, for further discussion and references.

4.8.3 Collateral Reading. For further information on the solutions of vibratory stresses and deflections, refer to Vibration Problems in Engineering, S. Timoshenko, 1974, and Structural Dynamics, Mario Paz, 1991.

Section 5: SNOW LOADS

5.1 General. Snow load provisions for the design of structures with basic roof configurations are established in this section. This information has been excerpted from the Army/Air Force manual TM 5-809-1/AFM 88-3, Chapter 1, Load Assumptions for Buildings, with some revisions.

5.2 Definitions. The following are definitions for snow load requirements:

5.2.1 Balanced Snow Load. Snow load, either P_f or P_s, applied to the entire horizontal projection of a roof.

5.2.2 Barrel-Vaulted Roof. A roof consisting of a series of segmental arches.

5.2.3 Exposure Factor, C_e. A factor to account for the effect of wind, due to site location, on the roof snow load.

5.2.4 Eaves. A margin or lower part of a roof. For a steeply sloped arched roof, the eaves are taken at the point where the slope is equal to 70 degrees.

5.2.5 Flat Roof. A roof with a slope less than 1 inch in 1 foot [5 degrees].

5.2.6 Ground Snow Load. Snow load on the ground based on a 50-year mean recurrence interval. (See Tables 6 and 7.)

5.2.7 Multiple Folded Plate Roof. A form of shell roof, consisting of a series of flat plates in a variety of shapes, such as V-shape, trapezoidal or Z-shape.

5.2.8 Slope Factor, C_s. A factor accounting for the decreased snow load on a sloped roof, due to sliding and improved drainage of meltwater.

5.2.9 Snow Load Importance Factor, I. A factor accounting for hazard to human life and damage to property.

5.2.10 Thermal Factor, C_t. A factor accounting for reduction in snow load by building heat.

5.2.11 Unbalanced Snow Load. Increased snow load applied to only a portion of a sloped roof. Unbalanced loads may develop on sloped roofs because of sunlight and wind. Wind tends to reduce snow loads on windward portions and increase snow loads on leeward portions.

5.3 Symbols. Snow load calculations in this section are based on the following symbols:

C_e = exposure factor (See Table 8)

C_s = slope factor (See Figure 5)

C_t = thermal factor (See Table 9)

h_b = height of balanced snow load, feet [meters]; i.e., balanced snow load, P_f or P_s, divided by appropriate density in Table 11

h_c = clear height from top of balanced snow load on lower roof to closest point on adjacent upper roof, feet [meters]

h_d = maximum height of snow drift, feet [meters]

I = snow load importance factor (See Table 10)

L = length of snow drift, feet [meters]; i.e., common length of upper and lower roofs

P_d = maximum intensity of drift surcharge, load, pounds per square foot [kPa]

P_f = flat roof design snow load, pounds per square foot [kPa]

P_g = ground snow load, pounds per square foot, based on a 50-year mean recurrence interval (See Figure 2, 3, or 4, and Tables 6 and 7)

P_s = sloped roof design snow load, pounds per square foot [kPa]. This is used as the balanced snow load for sloped roof.

s = separation distance between buildings, feet [meters]

w = width of snow drift, feet [meters]

[gamma] = snow drift density, pounds per cubic foot [kg/cu. m] (See Table 11)

[theta] = slope of a gable roof or equivalent slope of an arched roof, degrees

[phi] = slope of curve at a point on an arched roof, degrees

5.4 Ground Snow Loads, P_g. Ground snow loads, P_g are the basic data used to determine the design snow loads on roofs.

Table 6 provides the ground snow loads for major cities and installations in the United States. Snow loads for the contiguous United States are mapped in Figures 2, 3, and 4. In Alaska, extreme local variations preclude meaningful statewide mapping of ground snow loads; Table 6 provides ground snow loads for specific locations in Alaska.

Areas of extreme local variations in the contiguous United States are not zoned in Figures 2, 3, and 4, but are shown in black instead. In some other areas the snow load zones are meaningful, but the mapped values should not be used for certain geographic settings, such as high country within these zones. Such areas are shaded in Figures 2, 3, and 4, as a warning that the zoned value for those areas applies only to normal settings in them. For procedures in estimating site-specific ground snow loads for locations in the black and shaded areas in Figures 2, 3, and 4 and not shown in Table 6, refer to Cold Regions Research and Engineering Laboratory (CRREL) report, Snow Loads for the United States. Ground snow load data for specific locations outside the 50 states is provided in Table 7.

Table 6
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
ALABAMA:		
Anniston	5	.24
Maxwell AFB	0	0
Birmingham	5	.24
Huntsville	10	.48
Mobile	0	0
Montgomery	0	0
Fort Rucker	0	0
ALASKA:		
Adak Island	20	.96
Anchorage	65	3.1
Barrow	40	1.9
Bethel	35	1.7
Eielson AFB	60	2.9
Elmendorf AFB	65	3.1
Fairbanks	55	2.6
Fort Greely	60	2.9
Juneau	70	3.4
Kodiak Island	30	1.4
Nome	80	3.8
Palmer	50	2.4
Petersburg	130	6.2
Ft. Richardson	65	3.1
St. Paul Island	45	2.2
Seward	55	2.6
Shemya	20	.96
Sitka	45	2.2
Talkeetna	175	8.4
Unalakleet	55	2.6
Valdez	170	8.1
Ft. Wainwright	55	2.6
Whittier	400	19
Wrangell	70	3.4
Yakutat	175	8.4

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
ARIZONA:		
Fort Huachuca	5	.24
Luke AFB	0	0
Navajo AD	60	2.9
Phoenix	0	0
Tucson	5	.24
Williams AFB	0	0
Yuma	0	0
ARKANSAS:		
Blytheville AFB	10	.48
Fort Chaffee	5	.24
Little Rock AFB	5	.24
CALIFORNIA:		
Castle AFB	0	0
China Lake	10	.48
Edwards AFB	5	.24
Hamilton AFB	0	0
Hunter-Liggett MR	0	0
Long Beach	0	0
Los Angeles	0	0
March AFB	0	0
Mare Island	0	0
Norton AFB	0	0
Oakland	0	0
Fort Ord	0	0
Camp Pendelton	0	0
Port Hueneme	0	0
Sacramento	0	0
San Diego	0	0
San Francisco	0	0
Sharpe AD	0	0
Sierra AD	15	.72
Travis AFB	0	0
Vandenberg AFB	0	0

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
COLORADO:		
USAF Academy	30 [1]	1.4 [1]
Fort Carson	15 [1]	.72 [1]
Denver	15 [1]	.72 [1]
Fitzsimons AMC	15 [1]	.72 [1]
Peterson AFB	15 [1]	.72 [1]
Pueblo	10	.48 [1]
CONNECTICUT:		
Hartford	30	1.4
New Haven	25	1.2
New London	25	1.2
DELAWARE:		
Dover AFB	20	.96
Wilmington	15	.72
FLORIDA:		
Eglin AFB	0	0
Homestead AFB	0	0
Jacksonville	0	0
Key West	0	0
MacDill AFB	0	0
Miami	0	0
Orlando	0	0
Patrick AFB	0	0
Pensacola	0	0
Tampa	0	0
Tyndall AFB	0	0

[1] Determine drift load based on the ground snow load. Minimum roof snow load is 30 pounds per square foot [1.4 kPa] based upon local practice.

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
GEORGIA:		
Albany	0	0
Atlanta	5	.24
Fort Benning	5	.24
Fort Gordon	5	.24
Hunter AAF	0	0
Macon	5	.24
Robbins AFB	5	.24
Savannah	0	0
Fort Stewart	0	0
HAWAII:		
Barbers Point, Oahu	0	0
Hickam AFB	0	0
Hilo, Hawaii	0	0
Honolulu, Oahu	0	0
Kaneohe Bay, Oahu	0	0
Lihue, Kauai	0	0
Schofield Barracks	0	0
Wheeler AFB	0	0
IDAHO:		
Idaho Falls	25	1.2
Mountain Home AFB	15	.72
ILLINOIS:		
Chanute AFB	20	.96
Chicago	25 [2]	1.2 [2]
Great Lakes TC	25	1.2
Joliet AAP	25	1.2
O'Hare IAP	25 [2]	1.2 [2]
Rock Island Arsenal	20	.96
Savanna AD	30 [2]	1.4 [2]
Scott AFB	15	.72

[2] Determine drift load based on the ground snow load. Minimum roof snow load is 25 pounds per square foot [1.2 kPa] based upon local practice.

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
INDIANA:		
Fort Ben Harrison	20	.96
Fort Wayne	20	.96
Grissom AFB	20	.96
Indiana AAP	15	.72
IOWA:		
Burlington	20	.96
Cedar Rapids	35	1.7
Des Moines	25	1.2
Sioux City	35	1.7
KANSAS:		
Kansas AAP	15	.72
Fort Leavenworth	20	.96
McConnell AFB	15	.72
Fort Riley	20	.96
Sunflower AAP	20	.96
KENTUCKY:		
Fort Campbell	15	.72
Fort Knox	15	.72
Lexington	15	.72
Louisville	15	.72
LOUISIANA:		
Fort Polk	5	.24
Lake Charles	0	0
Louisiana AAP	5	.24
New Orleans	0	0
Shreveport	5	.24
MAINE:		
Bangor	80	3.8
Brunswick	60	2.9
Loring AFB	100	4.8
Winter Harbor	60	2.9

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
MARYLAND:		
Aberdeen Proving Ground	20	.96
Andrews AFB	20	.96
Annapolis	20	.96
Baltimore	20	.96
Fort Detrick	35	1.7
Edgewood Arsenal	20	.96
Fort Meade	20	.96
Fort Ritchie	35	1.7
MASSACHUSETTS:		
Boston	30	1.4
Fort Devens	45	2.2
L.G. Hanscom Field	40	1.9
Otis AFB	30	1.4
Westover AFB	30	1.4
MICHIGAN:		
Detroit	20	.96
Kincheloe AFB	70	3.4
K.I. Sawyer AFB	60	2.9
Selfridge AFB	20	.96
Wurtsmith AFB	50	2.4
MINNESOTA:		
Duluth	65	3.1
Minneapolis	50	2.4
MISSISSIPPI:		
Biloxi	0	0
Columbus AFB	10	.48
Jackson	5	.24
Keesler AFB	0	0
Meridian	5	.24

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
MISSOURI:		
Kansas City	20	.96
Lake City AAP	20	.96
Fort Leonard Wood	15	.72
St. Louis	20	.96
Richards Gebaur AFB	20	.96
Whiteman AFB	20	.96
MONTANA:		
Helena	20	.96
Malmstrom ABF	20	.96
Missoula	25	1.2
NEBRASKA:		
Cornhusker AAP	25	1.2
Lincoln	25	1.2
Offutt AFB	25	1.2
Omaha	25	1.2
NEVADA:		
Carson City	25	1.2
Fallon	10	.48
Hawthorne	15	.72
Las Vegas	5	.24
Wells	15	.72
NEW HAMPSHIRE:		
Hanover	55	2.6
Pease AFB	50	2.4
Portsmouth	50	2.4
NEW JERSEY:		
Atlantic City	15	.72
Bayonne	20	.96
Fort Monmouth	25	1.2
McGuire AFB	20	.96
Picatinny Arsenal	35	1.7

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
NEW MEXICO:		
Albuquerque	10	.48
Cannon AFB	10	.48
Hollomon AFB	5	.24
White Sands MR	5	.24
NEW YORK:		
Albany	30	1.4
Buffalo	40	1.9
Fort Drum	60	2.9
Griffiss AFB	50	2.4
New York City	20	.96
Niagara Falls IAP	30	1.4
Plattsburg AFB	40	1.9
Syracuse	45	2.2
Watervliet	30	1.4
West Point Military Reservation	35	1.7
NORTH CAROLINA:		
Fort Bragg	10	.48
Charlotte	10	.48
Camp Lejeune	10	.48
Greensboro	15	.72
Pope AFB	10	.48
Seymour Johnson	10	.48
Sunny Point Ocean Terminal	10	.48
NORTH DAKOTA:		
Bismarck	30	1.4
Fargo	35	1.7
Grand Forks AFB	40	1.9
Minot AFB	35	1.7
OHIO:		
Cincinnati	15	.72
Cleveland	20	.96
Columbus	15	.72

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
OHIO (Continued):		
Ravenna AAP	15	.72
Wright-Patterson AFB	15	.72
OKLAHOMA:		
Enid/Vance AFB	10	.48
Fort Sill	5	.24
Tinker AFB	10	.48
Tulsa	10	.48
OREGON:		
Coos Bay	5	.24
Eugene	20	.96
Portland	15	.72
Umatilla AD	15	.72
PENNSYLVANIA:		
Carlisle Barracks	25	1.2
Harrisburg	25	1.2
Letterkenny AD	30	1.4
Philadelphia	15	.72
Pittsburgh	25	1.2
Scranton	25	1.2
RHODE ISLAND:		
Newport	25	1.2
Providence	25	1.2
SOUTH CAROLINA:		
Charleston	5	.24
Fort Jackson	10	.48
Parris Island	0	0
Shaw AFB	5	.24
SOUTH DAKOTA:		
Ellsworth AFB	15	.72
Pierre	35	1.7
Sioux Falls	40	1.9

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
TENNESSEE:		
Chattanooga	5	.24
Holston AAP	15	.72
Memphis	10	.48
Milan AAP	10	.48
Nashville	10	.48
TEXAS:		
Austin/Bergstrom AFB	5	.24
Corpus Christi	0	0
Dallas	5	.24
Dyess AFB	5	.24
Ellington AFB	0	0
El Paso	5	.24
Fort Hood	5	.24
Fort Worth	5	.24
Galveston	0	0
Houston	0	0
TEXAS (continued):		
Lone Star AAP	5	.24
Reese AFB	15	.72
San Antonio	5	.24
Wichita Falls	5	.24
UTAH:		
Dugway P.G.	10	.48
Hill AFB	35	1.7
Salt Lake City	15	.72
Tooele Army Depot	30	1.4
VERMONT:		
Bennington	50	2.4
Burlington	40	1.9
Montpelier	70	3.4
St. Albans	40	1.9

Table 6 (Continued)
Snow Data for Locations Inside the 50 States

Location	Ground Snow Load (psf)	[kPa]
VIRGINIA:		
Fort Belvoir	20	.96
Fort Eustis	10	.48
Fort Myer	20	.96
Norfolk	10	.48
Petersburg/Fort Lee	15	.72
Quantico	20	.96
Radford AAP	25	1.2
Richmond	15	.72
WASHINGTON:		
Bremerton	20	.96
Fairchild AFB	40	1.9
Fort Lewis	20	.96
McChord AFB	20	.96
Seattle	15	.72
Walla Walla	15	.72
Yakima	25	1.2
WASHINGTON, DC:		
Bolling AFB	20	.96
Fort McNair	20	.96
Walter Reed AMC	20	.96
WEST VIRGINIA:		
Charleston	20	.96
Sugar Grove	30	1.4
WISCONSIN:		
Badger AAP	35	1.7
Fort McCoy	40	1.9
Green Bay	40	1.9
Madison	35	1.7
Milwaukee	35	1.7
Osceola	55	2.6
WYOMING:		
Cheyenne	15	.72
Yellowstone	60	2.9

Table 7
Snow Data for Locations Outside the 50 States

Location	Ground Snow Load (psf)	[kPa]
AFRICA:		
Libya:		
Wheelus AB	0	0
Morocco:		
Casablanca	0	0
Port Lyautey NAS	0	0
ASIA:		
India:		
Bombay	0	0
Calcutta	0	0
Madras	0	0
New Delhi	0	0
Japan:		
Itazuke AB	10	.48
Johnson AB	10	.48
Misawa AB	20	.96
Tachikawa AB	10	.48
Tokyo	10	.48
Wakkanai	55	2.6
Korea:		
Kimpo AB	20	.96
Seoul	20	.96
Uijongbu	15	.72
Pakistan:		
Peshawar	10	.48
Saudi Arabia:		
Bahrain Island	0	0
Dhahran AB	0	0

Table 7 (Continued)
Snow Data for Locations Outside the 50 States

Location	Ground Snow Load (psf)	Ground Snow Load [kPa]
Taiwan:		
Tainan	0	0
Taipei	0	0
Thailand:		
Chiang Mai	0	0
Bangkok	0	0
Sattahip	0	0
Turkey:		
Ankara	20	.96
Karamursel	15	.72
Vietnam:		
Saigon	0	0
ATLANTIC OCEAN AREA:		
Ascension Island	0	0
Azores:		
Lajes Field	0	0
Bermuda	0	0
CARIBBEAN SEA:		
Bahama Islands:		
Eleuthera Island	0	0
Grand Bahama Island	0	0
Grand Turk Island	0	0
Great Exuma Island	0	0
Cuba:		
Guantanamo NAS	0	0

Table 7 (Continued)
Snow Data for Locations Outside the 50 States

Location	Ground Snow Load (psf)	[kPa]
Leeward Islands:		
Antigua Island	0	0
Puerto Rico:		
Boringuen Field	0	0
San Juan and Sabana Seca	0	0
Vieques Island and Roosevelt Roads	0	0
Virgin Islands	0	0
Trinidad Island:		
Port of Spain	0	0
Trinidad NS	0	0
CENTRAL AMERICA:		
Canal Zone:		
Albrook AFB	0	0
Balboa	0	0
Coco Solo	0	0
Colon	0	0
Cristobal	0	0
France AFB	0	0
EUROPE:		
England:		
Birmingham	15	.72
London	15	.72
Mildenhall AB	15	.72
Plymouth	10	.48
Sculthorpe AB	15	.72
Southport	10	.48
South Shields	15	.72
Spurn Head	15	.72

Table 7 (Continued)
Snow Data for Locations Outside the 50 States

Location	Ground Snow Load (psf)	[kPa]
France:		
Nancy	15	.72
Paris/Le Bourget	20	.96
Rennes	15	.72
Vichy	25	1.2
Germany:		
Bremen	25	1.2
Munich-Riem	40	1.9
Rhein-Main AB	25	1.2
Stuttgart AB	45	2.2
Greece:		
Athens	5	.24
Iceland:		
Keflavik	30	1.4
Thorshofn	30	1.4
Italy:		
Aviano AB	10	.48
Brindisi	5	.24
Scotland:		
Aberdeen	15	.72
Edinburgh	15	.72
Edzell	15	.72
Glasgow/Renfrew Airfield	15	.72
Lerwick, Shetland Islands	15	.72
Londonderry	15	.72
Prestwick	15	.72
Stornoway	15	.72
Thurso	15	.72
Spain:		
Madrid	10	.48
Rota	5	.24

Table 7 (Continued)
Snow Data for Locations Outside the 50 States

Location	Ground Snow Load (psf)	[kPa]
EUROPE (continued):		
Spain (continued):		
San Pablo	5	.24
Zaragoza	10	.48
NORTH AMERICA:		
Canada:		
Argentia NAS, Newfoundland	47	2.3
Churchill, Manitoba	66	3.2
Cold Lake, Alberta	41	2.0
Edmonton, Alberta	27	1.3
E. Harmon AFB, Newfoundland	86	4.1
Fort William, Ontario	73	3.5
Frobisher, N.W.T.	50	2.4
Goose Airport, Newfoundland	100	4.8
Ottawa, Ontario	60	3.4
St. John's, Newfoundland	72	3.5
Toronto, Ontario	40	1.9
Winnipeg, Manitoba	45	2.2
Greenland:		
Narsarssuak AB	30	1.4
Simiutak AB	25	1.2
Sondrestrom AB	20	.96
Thule AB	25	1.2
PACIFIC OCEAN AREA:	Zero, unless local experience indicates otherwise	

Table 8
Exposure Factor, C_e

Exposure Category	Siting of Structure[1]	C_e
A	Windy areas, roof exposed on all sides with no shelter[2] afforded by terrain, higher structures, or trees.	0.8
B	Windy areas with little shelter[2] available.	0.9
C	Snow removal by wind cannot be relied on to reduce roof loads because of terrain, higher structures, or several trees nearby.	1.0
D	Areas that do not experience much wind and where terrain, higher structure, or several trees shelter[2] the roof.	1.1
E	Densely forested areas that experience little wind with roof located tightly among conifers.	1.2

[1] These conditions should be representative of those that are likely to exist during the life of the structure. Roofs which contain several large pieces of mechanical equipment or other obstructions do not qualify for Exposure Category A.

[2] Obstructions within a distance of $10h_o$ provide shelter, where h_o is the height of the obstruction above the roof level. Deciduous trees are leafless in winter. If the obstruction is created by deciduous trees only, C_e may be reduced 0.1.

Table 9
Thermal Factor, C_t

Thermal Condition[1]	C_t
Heated structure	1.0
Structure kept just above freezing	1.1
Unheated structure	1.2

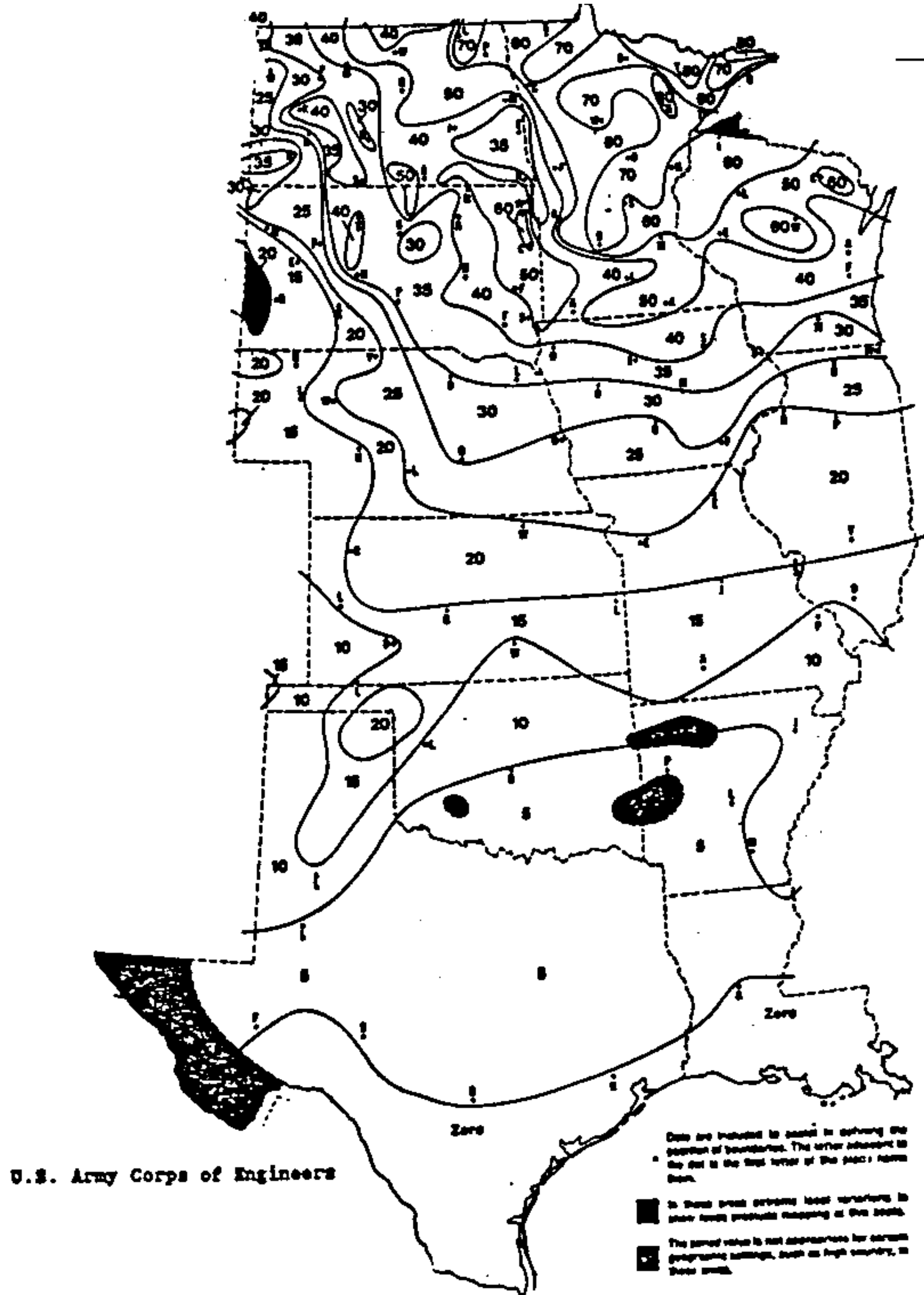
[1] These conditions should be representative of those that are likely to exist during the life of the structure.

Table 10
Snow Load Importance Factor, I

Building Category	Occupancy	Snow Load Importance Factor, I
I	All buildings except those listed below	1.0
II	High Risk . Buildings where primary occupancy is for assembly of 300 or more people in one area; e.g., auditoriums, recreation facilities, dining halls, commissaries, etc. . Buildings having high value equipment. . Facilities involving missile operations. . Facilities involving sensitive munitions, fuels, chemical and biological contaminants.	1.1
III	Essential Facilities . Buildings housing critical facilities which are necessary for post-disaster recovery and require continuous operation; e.g., hospitals, power stations, fire stations, buildings, and other structures housing mission-essential operations.	1.2

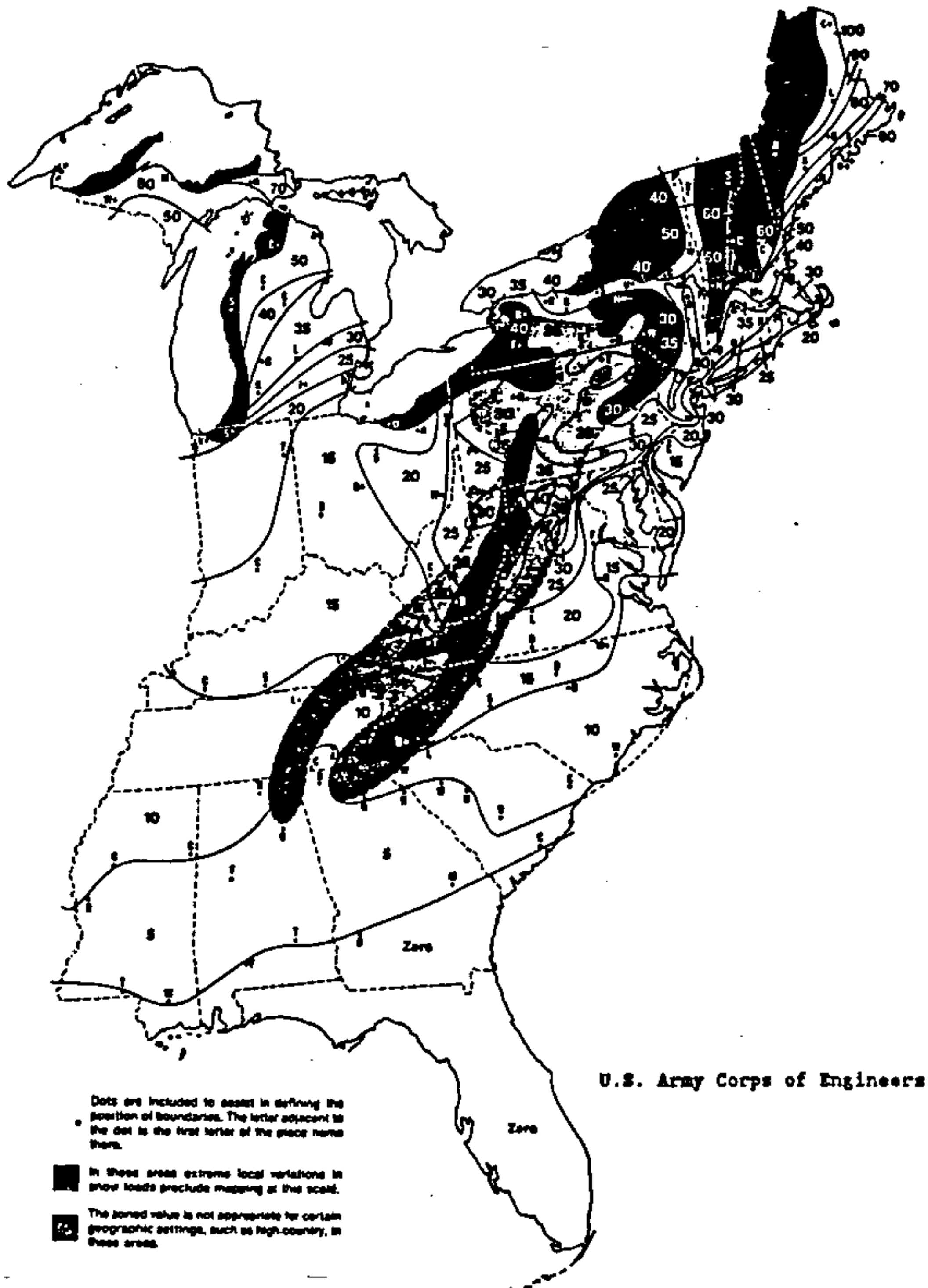
Multiply values shown in "psf" by .04788 to get values in "kPa"

Figure 2
Ground Snow Loads, P_g, Western United States



Multiply values shown in "psf" by .04788 to get values in "kPa"

Figure 3
Ground Snow Loads, P_g, Central United States



Multiply values shown in "psf" by .04788 to get values in "kPa"

Figure 4
Ground Snow Loads, P_g, Eastern United States

5.5 Flat Roof Snow Loads. Calculate the snow load, P_f on an unobstructed flat roof using the following:

EQUATION: Contiguous United States
and areas outside the 50 States (2)

$$P_f = 0.7\, C_e C_t I\, P_g$$

Equation: Alaska (3)

$$P_f = 0.6\, C_e C_t I P_g$$

5.5.1 Exposure Factor. Consider wind effects in design by applying the exposure factors in Table 8.

5.5.2 Thermal Factor, C_t. Consider thermal effects in design by applying the thermal factors in Table 9.

5.5.3 Snow Load Importance Factor. For structures where the consequences of failure are more serious than normal, increase design loads above normal. Appropriate values for I are presented in Table 10.

5.5.4 Minimum Roof Snow Load. The minimum snow load, P_f is applicable only to low sloped roofs as defined by [theta] below:

pitched roof [theta] < 15 degrees

arched roof [theta] < 10 degrees

The minimum P_f for such roofs follow:

if P_g < / = 20 pounds per square foot [.96 kPa],
then minimum $P_f = P_g I$

if P_g > / = 20 pounds per square foot [.96 kPa],
then minimum P_f = 20I [.96I in "kPa"].

5.6 Sloped Roof Snow Loads, P_s. Consider snow loads acting on a sloping surface to act on the horizontal projection of that surface. To obtain the sloped roof snow load, P_s multiply the flat roof snow load, P_f by the roof slope factor, C_s:

EQUATION: $$P_s = C_s P_f \tag{4}$$

Values of C_s for warm and cold roofs are given in Figure 5.

5.6.1 Warm Roof Slope Factor, C_s. For roofs (C_t = 1.0 in Table 9) with a slippery surface that will allow snow to slide off the eaves, determine the roof slope factor, C_s using the dashed line in Figure 5(a). For other warm roofs that cannot be relied on to shed snow loads by sliding, use the solid line in Figure 5(a) to determine the roof slope factor, C_s.

5.6.2 Cold Roof Slope Factor, C_s. For roofs (C_t > 1.0 in Table 9) with a slippery surface that will allow snow to slide off the eaves, determine the roof slope factor, C_s using the dashed line in Figure 5(b). For other cold roofs that cannot be relied on to shed snow loads by allowing the snow to slide off, use the solid line in Figure 5(b) to determine the roof slope factor, C_s.

5.6.3 Roof Slope Factor for Arched Roofs. Consider portions of arched roofs having a slope exceeding 70 degrees to be free of snow load. The point at which the slope equals 70 degrees will be considered the eaves for such roofs. For arched roofs, determine the roof slope factor, C_s from the appropriate curve in Figure 5 by basing the slope on the vertical angle from the eaves to the crown.

5.6.4 Roof Slope Factor for Multiple Folded Plate and Barrel-Vaulted Roofs. No reduction for snow load in the valleys will be applied because of slope (i.e., C_s = 1.0 regardless of slope and, therefore, $P_s = P_f$).

5.7 Unloaded Portions. Consider the effect of removing half the balanced snow load from any portion of the loaded area.

5.8 Unbalanced Roof Snow Loads. Consider winds from all directions when establishing unbalanced loads.

5.8.1 Unbalanced Snow Loads for Hip and Gable Roofs. For hip and gable roofs with a slope, [theta], less than 15 degrees or exceeding 70 degrees, unbalanced snow loads need not be considered. Consider roofs having a slope, [theta], exceeding 70 degrees free of snow. For slope [theta], between 15 and 70 degrees, design the structure to sustain an unbalanced uniform snow load. The unbalanced load will be on the leeward side and will be equal to 1.5 times the sloped roof snow load, P_s, divided by C_e (i.e., $1.5P_s/C_e$). The windward side will be considered free of snow. Balanced and unbalanced loading diagrams are presented in Figure 6.

5.8.2 Unbalanced Snow Loads for Arched Roofs. The equivalent slope, [theta], of an arched roof for use in Figure 5 is equal to the slope of a line from the eaves to the crown. If the equivalent slope, [theta], is less than 10 degrees or greater than 60 degrees, unbalanced snow loads need not be considered. For equivalent slopes, [theta], between 10 and 60 degrees, determine unbalanced loads according to the loading diagrams in Figure 7. The windward side will be considered free of snow. Additionally, portions of arched roofs having a slope, [theta], exceeding 70 degrees will be considered free of snow. If the ground or another roof abuts a Case II or Case III arched roof structure (see Figure 7) at or within 3 feet [900 mm] vertically of the eaves, the snow load will not be decreased between the 30-degree point and the eaves, but will remain constant at $2P_sC_e$. This alternative distribution is shown as a dashed line in Figure 7.

5.8.3 Unbalanced Snow Loads for Multiple Folded Plate and Barrel-Vaulted Roofs. In the roof valleys, C_s equals 1.0 and accordingly the balanced snow load equals P_f. The unbalanced snow load will increase from one-half the balanced load at the ridge or crown (i.e., $0.5P_f$) to three times the balanced load divided by C_e at the valley (i.e., $3P_f/C_e$). However, the snow surface above the valley, assuming a density from Table 11, will not be at an elevation higher than that above the ridge. This may limit the unbalanced load to somewhat less than $3P_f/C_e$. The unbalanced snow loading at the windward and leeward slopes will be as follows:

Roof	First Windward Slope	Last Leeward Slope
Multiple folded plate	No snow	See Figure 6
Barrel vault	No snow	See Figure 7

Table 11
Densities for Use in Establishing Drift Loads

Ground Snow Load, P_s (psf) [kPa]	Drift Density, [gamma] (pcf) [N/cu. m]
1-10 [.05-.48]	Drifting not considered
11-30 [.49-1.4]	15 [2400]
31-60 [1.5-2.9]	20 [3200]
Greater than 60 [2.9]	25 [4000]

Balanced and unbalanced loading diagrams for a multiple plate roof are presented in Figure 8.

5.9 Drifts on Lower Roofs. Design roofs to sustain localized loads from snow drifts expected to accumulate on them in the wind shadow of higher portions of the same structure, adjacent structures, or terrain features.

5.9.1 Regions With Light Snow Loads. In areas where the ground snow load, P_g is 10 pounds per square feet (psf) [.48 kPa] or less, drift loads on lower roofs need not be considered.

5.9.2 Lower Roof of a Building. The geometry of the surcharge load due to snow drifting is approximated by a triangle, as shown in Figure 9. It is assumed that snow is blown off the upper roof near its eave. If h_c/h_b is less than 0.2, drift loads need not be considered. Calculate drift height, h_d:

$$h_d = \frac{2\ IP_g}{C_e[\text{gamma}]} \quad \text{(feet) or} \qquad (5)$$

$$h_d = \frac{203\ 500\ IP_g}{C_e[\text{gamma}]} \quad \text{[mm]} \qquad (6)$$

where [gamma] is defined in Table 11. The drift height will not be greater than h_c. Drift width, w, will equal $3h_d$ if L is less than, or equal to, 50 feet [15 200 mm] and will equal $4h_d$ if L is greater than 50 feet [15 200 mm]; however, w will not be less than 10 feet [3050 mm]. If w exceeds the width of the lower roof, the drift will be truncated at the far edge of the roof, not reduced to zero there. The maximum intensity of the drift surcharge load, P_d, equals [gamma] h_d.

5.9.3 Adjacent Buildings and Terrain Features. To establish loads caused by drifting on the roof of a building within 20 feet [6100 mm] of a higher building or terrain feature, follow procedures of par. 5.9.2. The separation distance, s, between the two buildings will reduce drift loads on the lower roof. Apply the factor (20 - s)/20 in feet or [(6100 - s)/6100 in mm] to the intensity of the maximum drift load to account for spacing. (See Figure 10.) For separations greater than 20 feet [6100 mm], drift loads from adjacent structure or terrain feature need not be considered.

5.10 Roof Projections. A continuous projection longer than 15 feet [4600 mm] may produce a significant drift on a roof. Consider the loads caused by such a drift to be distributed triangularly on all sides of the obstruction that are longer than 15 feet [4600 mm]. Refer to par. 5.9.2 to determine the drift surcharge loads and the width of the drift.

5.11 Sliding Snow. Snow may slide off a sloped roof onto a lower roof, creating extra loads on the lower roof. Determine the extra load by assuming that snow that could accumulate on the upper roof under the balanced loading condition slides onto the lower roof. Use the solid lines in Figure 5 to determine the snow that could accumulate on the upper roof. Do not use the dashed line regardless of the surface of the upper roof. For conditions where a portion of the upper roof load is expected to slide clear of the lower roof, reduce the sliding snow load on the lower roof accordingly.

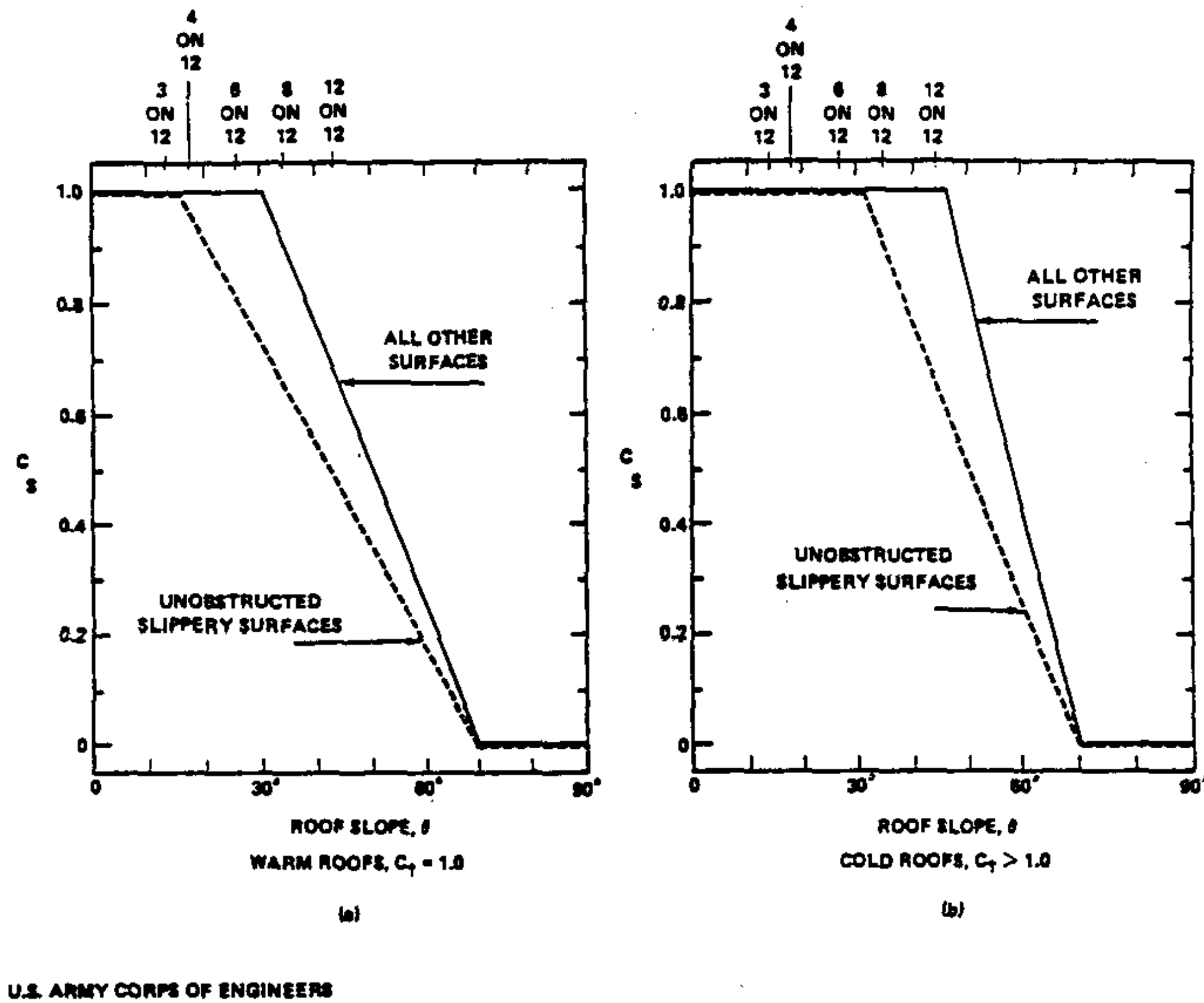


Figure 5
Graphs for Determining Roof Slope Factor C_s

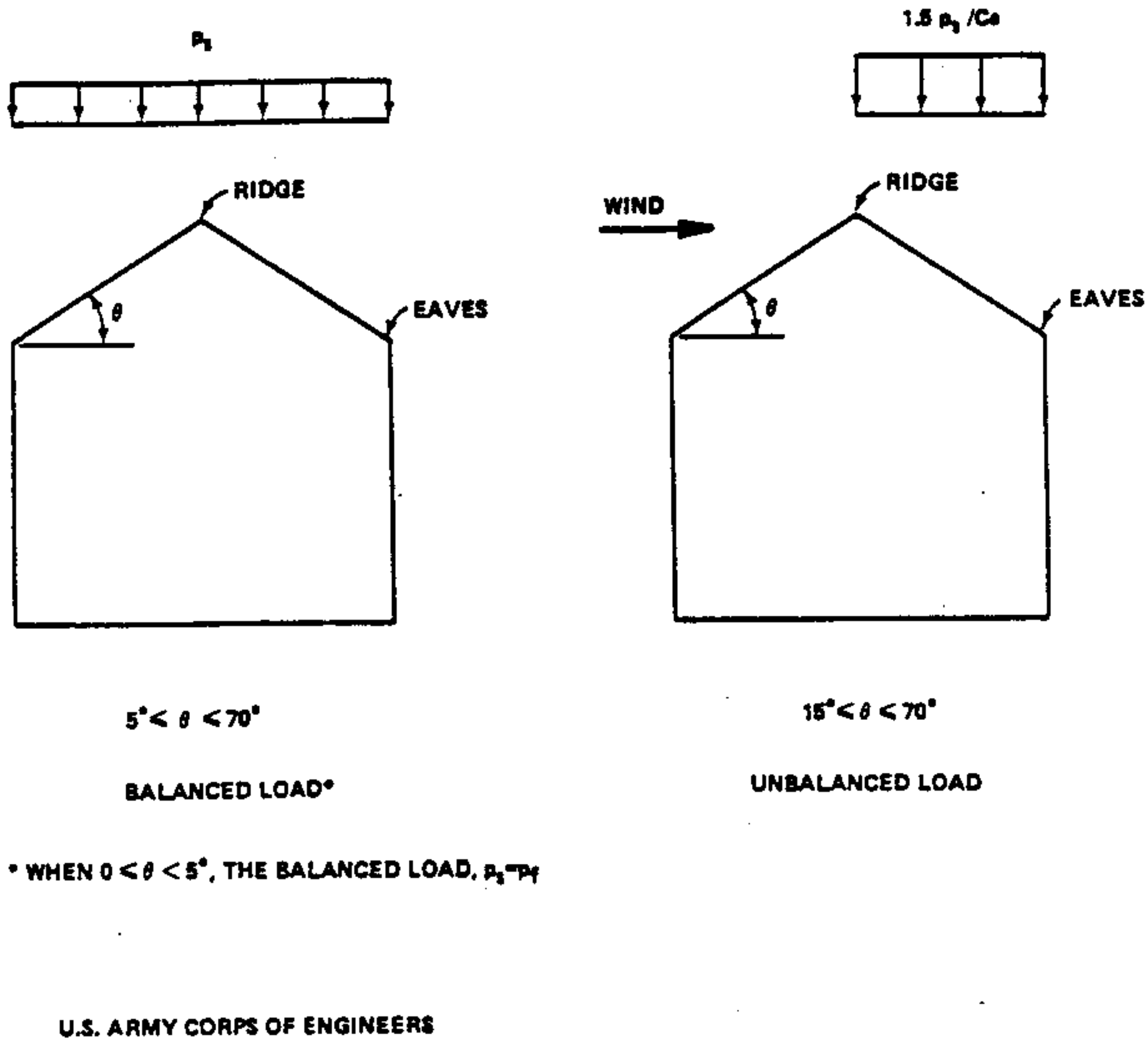


Figure 6
Balanced and Unbalanced Snow Loads Hip and Gable Roofs

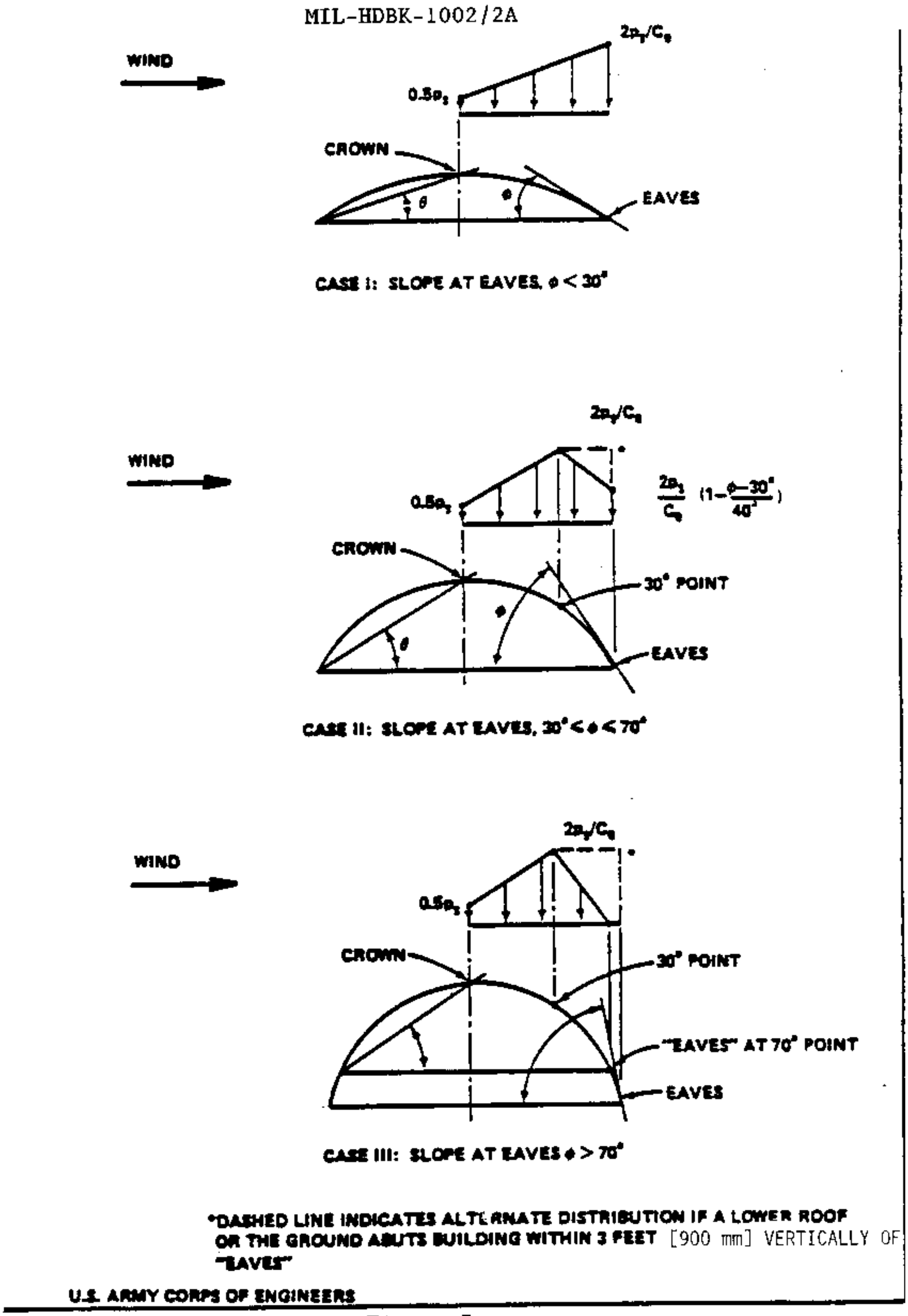


Figure 7
Unbalanced Loading Conditions for Arched Roofs
10 Degrees < [theta] < 60 Degrees

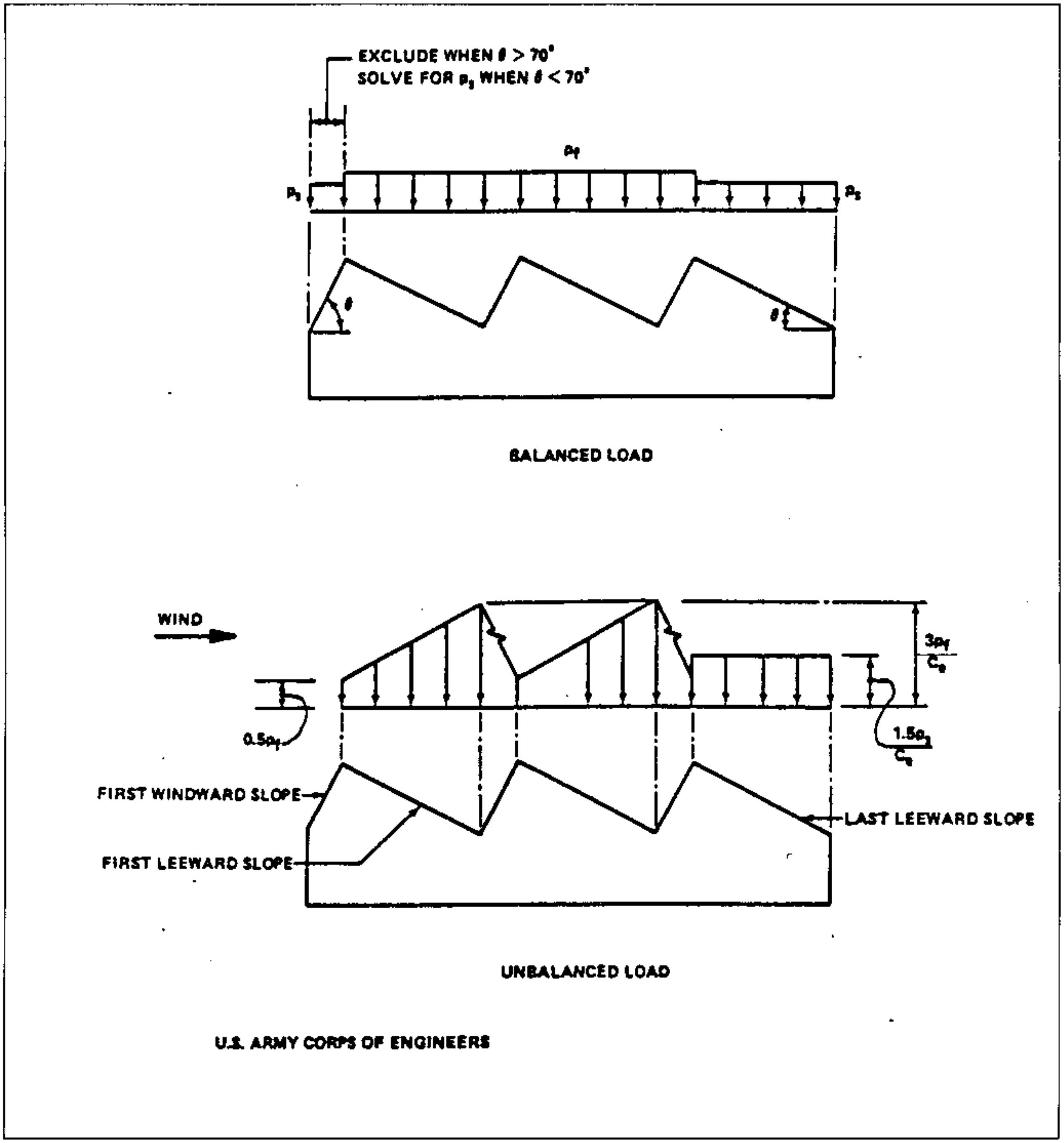
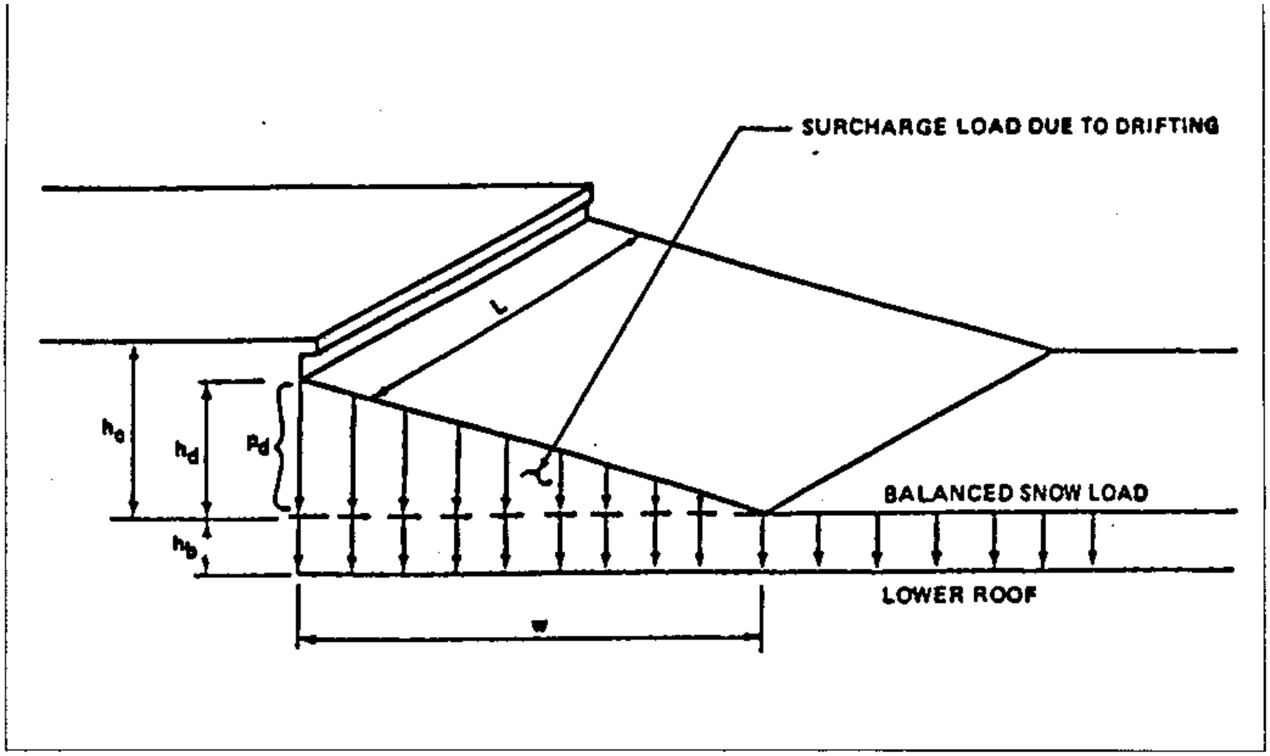


Figure 8
Balanced and Unbalanced Snow Loads Multiple Folded Plate Roof



When $\frac{h_c}{h_b} \geq 0.2$

$$h_d = \frac{2\ IP_g}{C_e[\text{gamma}]} \leq h_c \text{ (feet) or } h_d = \frac{203\ 500\ IP_g}{C_e[\text{gamma}]} \leq h_c \text{ [mm]}$$

If L $\leq$ 50 ft. [15 200 mm]; w = $3h_d \geq$ 10 ft. [3050 mm]

If L > 50 ft. [15 200 mm]; w = $4h_d \geq$ 10 ft. [3050 mm]

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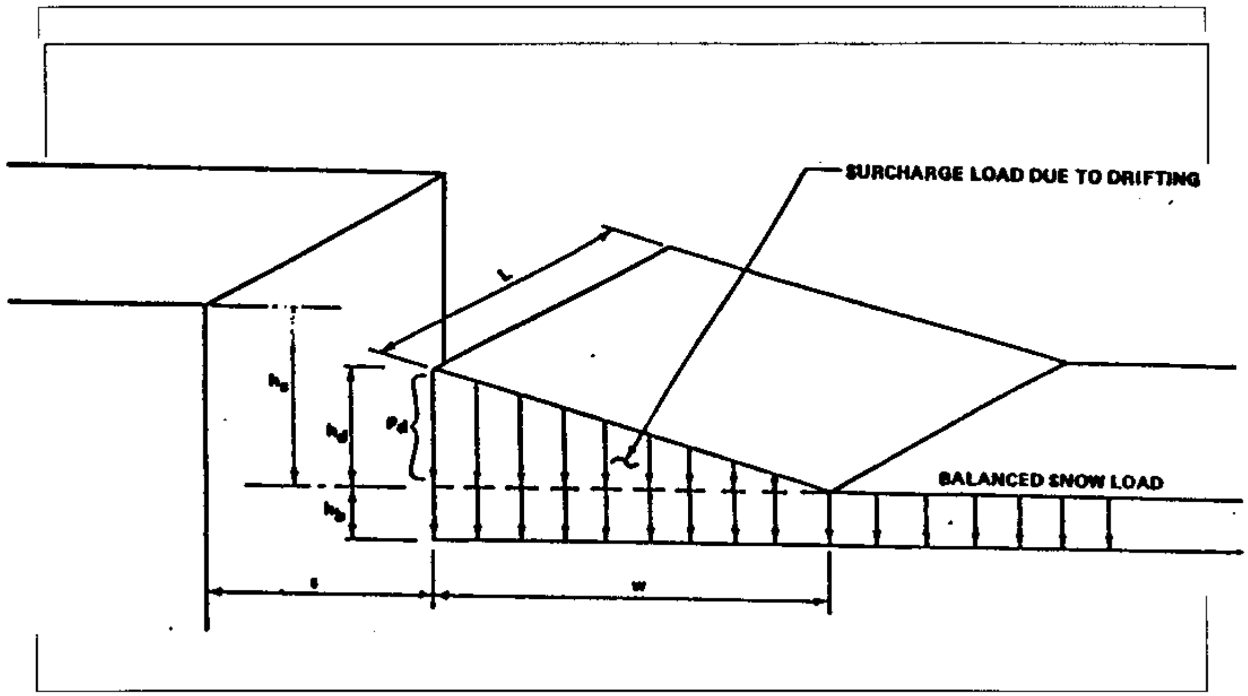
Figure 9
Configuration of Drift on Lower Roofs

When hc > 0.2
hb
hd = 2 IPg < hc (feet) or hd = 203 500 IPg < hc [mm]
Ce[gamma] Ce[gamma]

If L < 50 ft. [15 200 mm]; w = 3hd > 10 ft. [3050 mm]

If L > 50 ft. [15 200 mm]; w = 4hd > 10 ft. [3050 mm]



When $\dfrac{h_c}{h_b} \geq 0.20$

$$h_d = \frac{2\ IP_g}{C_e[\text{gamma}]}\ \frac{(20-s)}{(20)} \leq h_c\ \text{(feet) or}\ \frac{203\ 500\ IP_g}{C_e[\text{gamma}]}\ \frac{(6100-s)}{(6100)} \leq h_c\ \text{[mm]}$$

If L $\leq$ 50 ft. [15 200 mm]; w = $3h_d \geq$ 10 ft. [3050 mm]

If L > 50 ft. [15 200 mm]; w = $4h_d \geq$ 10 ft. [3050 mm]

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Figure 10
Configuration of Drift on Lower Roofs of a Separate Building

Building]

When hc > 0.20
hb

hd = 2 IPg (20-s) < hc (feet) or 203 500 IPg (6100-s) < hc [mm]
Ce[gamma] (20) Ce[gamma] (6100)

If L < 50 ft. [15 200 mm]; w = 3hd > 10 ft. [3050 mm]

If L > 50 ft. [15 200 mm]; w = 4hd > 10 ft. [3050 mm]

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Section 6: LOADS FOR SPECIAL STRUCTURES

6.1 Crane Runways, Trackage, and Supports. For impact, traction (including braking), and lateral forces, refer to Section 4. For other data, refer to DM-38.01, Weight-Handling Equipment.

6.2 Waterfront Structures. Load criteria for piers, wharves, and waterfront structures are discussed in detail in MIL-HDBK-1025/1, Piers and Wharves, MIL-HDBK-1025/4, Seawalls, Bulkheads, and Quaywalls, MIL-HDBK-1025/6, General Criteria for Waterfront Construction, and DM-26 Series, Harbor and Coastal Facilities.

6.3 Antenna Supports and Transmission Line Structures. Consider the following loads in design of antenna supports and transmission line structures.

6.3.1 Dead Load. Refer to Section 2.

6.3.2 Live Load on Stairways and Walkways. Refer to Section 3.

6.3.3 Wind Load. Refer to Section 7.

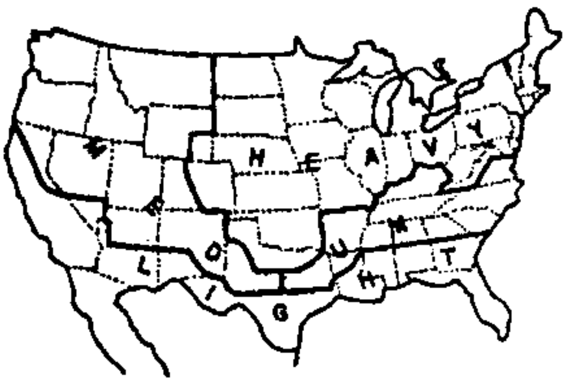
6.3.4 Ice Load. Determine the thickness of ice covering on guys, conductors, insulation, and framing supports from Figure 11. Exceptions are areas known to have more severe icing conditions, such as coastal and waterfront areas that are subject to heavy sea spray or high local precipitation. For ice load in these areas, consult cognizant Engineering Field Division (EFD) or Engineering Field Activity (EFA).

6.3.5 Thermal Changes. Consider changes in guy or cable sag or both due to temperature changes. Refer to Section 10.

6.3.6 Pretension Forces. Consider pretension forces in guys and wires in accordance with par. 4.3.3.2 of MIL-HDBK-1002/3, Steel Structures.

6.3.7 Broken Wires. Design support structures to resist the unbalanced pull or torsion resulting from broken guys in accordance with par. 4.3.3.2 of MIL-HDBK-1002/3, and for any reasonable incidence of broken transmission wires.

6.3.8 Erection Loads. Temporary erection loads are important in the design of antenna supports and transmission line structures.



(a) Geographic Distribution

Loading District	Radial Thickness of Ice (in.)	[mm]
Heavy	0.50	[13]
Medium	0.25	[6]
Light	None	[0]

(b) Thickness of Ice Covering

Figure 11
Ice Load on Antenna Supports and Transmission Line Structures

6.4 Turbine Generator Foundations. Consider the following loads in design of turbine generator foundations.

6.4.1 Vertical Loads. For component weights of the turbine generator and distribution of these weights, refer to the manufacturer's machine outline drawings. Increase machine loads 25 percent for impact for machines with speeds up to and including 1800 revolutions per minute (rpm), and 50 percent for those with higher speeds. Consider additional loads (such as auxiliary equipment, pipes, and valves) supported by the foundations.

6.4.2 Steam Condenser Load. Determine the condenser or vacuum load from the method of mounting the condenser.

6.4.3 Torque Loads. Torque loads are produced by magnetic reactions of electric motors and generators which tend to retard rotation. Use five times the normal torque in the design of the supporting members. For turbine generators, normal torque may be computed by the following equation:

EQUATION:

$$\text{torque (ft lb)} = \frac{7040\ (\text{kw})}{\text{rpm}} \qquad (7)$$

$$\text{torque (N m)} = \frac{9545\ \text{kw}}{\text{rpm}}$$

For other types of rotating machinery, use similar formulas.

6.4.4 Horizontal Loads on Support Framing

a) Longitudinal force. Assume a longitudinal force of 20 to 50 percent of the machine weight applied at the shaft centerline.

b) Transverse force. Assume a transverse force at each bent of 20 to 50 percent of the machine weight supported by the bent and applied at the machine centerline.

c) Longitudinal and transverse forces. Do not assume longitudinal and transverse forces act simultaneously.

6.4.5 Horizontal Forces Within Structure. Assume horizontal forces to be equal in magnitude to the vertical loads of the generator stator and turbine exhaust hood, as given on the manufacturer's machine outline drawings. Apply these forces at the top flange of the supporting girders; assume the forces to be equal and opposite.

6.4.6 Assumed Forces on Centerline Guides. Refer to the machine outline drawing for magnitude and points of application. Support beams for guide brackets shall have sufficient rigidity to limit the displacements relative to the main foundation to 0.005 inch [0.13 mm] under the action of the assumed forces.

6.4.7 Temperature Variation. Consider forces acting within the foundation due to temperature changes.

6.4.8 External Piping. Make provisions to withstand loads from pipe thrusts, relief valves, and the weight of piping and fittings.

Section 7: WIND LOADS

7.1 General. The procedures in this section together with the various equations, coefficients, and correction factors are intended to apply to structures of regular shape and to structures regularly used for human occupancy or containing valuable properties. Tornados were not considered in developing these criteria. Exceptions for minor and limited life structures are presented in MIL-HDBK-1002/1, Structural Engineering, General Requirements. Give special consideration to conditions at variance with the above. The criteria contained in this section are based on American National Standards Institute (ANSI) Standard A58.1, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures, modified for simplicity of application and interpretation.

7.2 Wind Pressure. Design buildings and other structures to withstand applicable wind pressure.

7.2.1 Velocity Pressure. Determine a velocity pressure (q) by the following:

EQUATION: $$q = 0.00256\ V^2 C_h \text{ (psf)} \tag{8}$$

EQUATION: $$q = 0.000613\ V^2 C_h \text{ [kPa]} \tag{9}$$

where: q = velocity pressure of wind (pounds per square foot) [kPa]

C_h = height correction factor

V = wind velocity (miles per hour) [m/s]

a) Wind Velocity. Peak gust wind speeds are given for the contiguous United States in Figure 12 and Table 12, and for locations outside the United States in Table 13. Use a minimum of 80 miles per hour [36 m/s] wind velocity for design.

b) Gust Factors. Gust factors are incorporated in the peak gust wind speeds given in Figure 12 and Tables 12 and 13. Use of the peak gust speed eliminates the need for estimation of the gust factor. The gust factor is variable, dependent on the general wind speed level at the particular location. The peak gust velocity indicated is assumed to be sustained for an interval of 2 to 3 seconds, and therefore ordinarily will be treated as a steady wind because the natural response period of most structures is less than 1.5 seconds. When the response period of the structure exceeds 1.5 seconds, use appropriate methods of analyses for dynamic forces.

c) Correction Coefficient for Height. Use curve A of Figure 13 to obtain the correction coefficient for velocity pressures above 30 feet [9.1 m]. Curve A is a plot of Equation (10). The correction factor, C_h below 30 feet [9.1 m] is equal to 1.0.

$$C_h = \left(\frac{h}{30}\right)^{2/7} \text{ (h in feet)} \qquad (10)$$

$$C_h = \left(\frac{h}{9.1}\right)^{2/7} \text{ [h in meters]} \qquad (11)$$

d) Correction for Exposure Conditions. Do not use correction coefficients for exposure with criteria in this section except with specific approval of NAVFAC Code 15C or NFESC ESC00CE5.

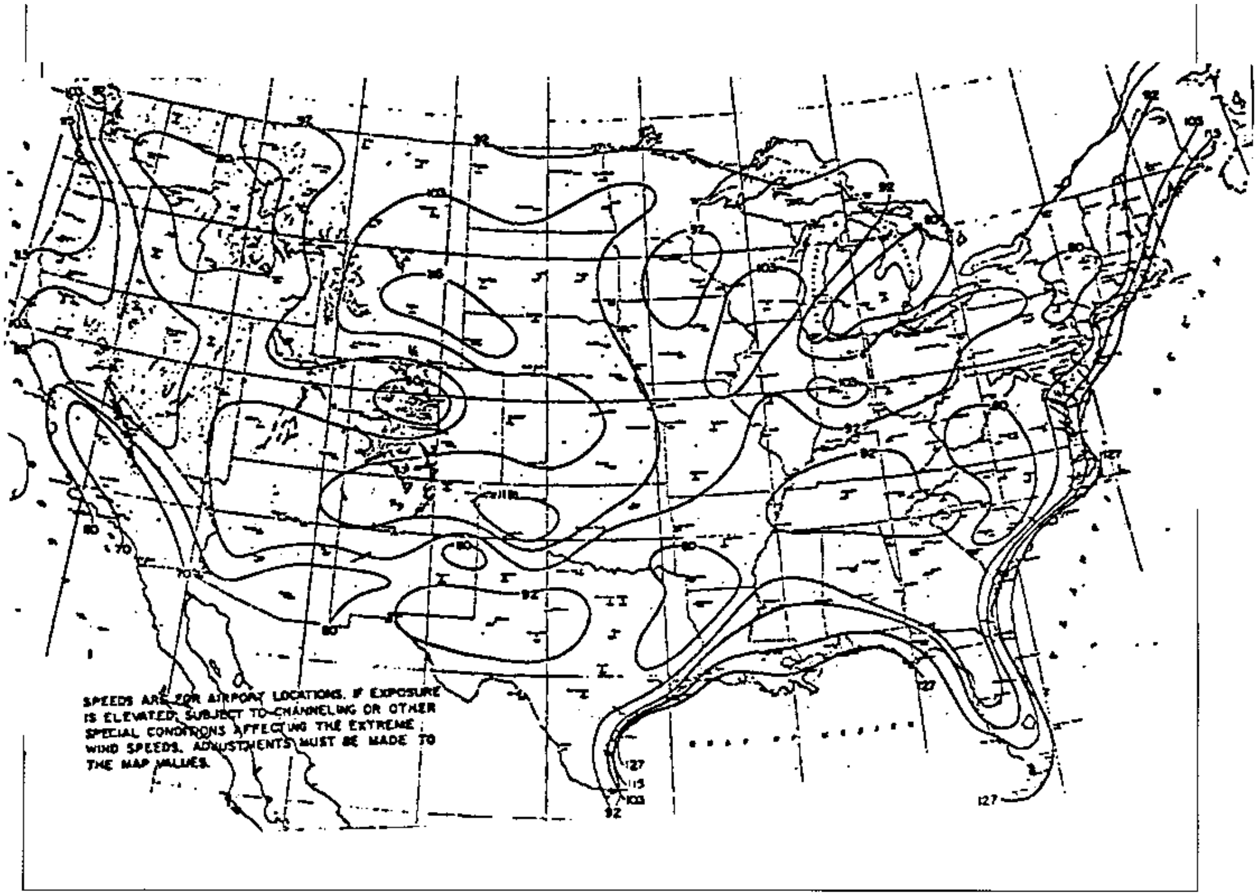
7.2.2 Design Wind Pressure. Determine the design wind pressure for elements of buildings and other structures by the applicable velocity pressure q (obtained in accordance with Equation (9) or Figure 13) and considering the correction coefficient for height multiplied by the applicable pressure coefficient (Tables 14 to 23 and Figures 14 to 17).

7.3 Purlins, Girts, Sheathing, Siding, Fastenings, Walls, and Doors. The design loading for purlins, girts, sheathing, siding, fastenings, walls, and doors consider:

a) Negative external pressure (suction) plus internal pressure acting outward as a bursting force.

b) External pressure, plus internal pressure acting inward as an internal suction.

c) In the above loading combinations, the internal pressures are assumed to be uniformly distributed over the interior surface of the building.



Multiply values in "mph" by .44704 to get "m/s"

Figure 12
Peak Gust Windspeeds (mph) [m/s] at 30 Feet [9.1 m] Aboveground
(25-year Recurrence Interval)

Table 12
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
ALABAMA:				
Brooklyn AFB, Mobile	121	54	6	150
Maxwell AFB, Montgomery	91	41	9	230
Mobile	121	54	6	150
Montgomery	91	41	6	150
ARIZONA:				
Davis Monthan AFB, Tucson	76*	34*	91	2300
Luke AFB, Phoenix	91	41	7	180
Williams AFB, Phoenix	78*	35*	7	180
Phoenix	81	36	7	180
ARKANSAS:				
Little Rock AFB, Little Rock	90	40	15	380
CALIFORNIA:				
Castle AFB, Merced	61*	27*	5	130
Hamilton AFB, San Francisco	84	38	5	130
March AFB	59*	26*	5	130
Mather AFB, Sacramento	101	45	5	130
Travis AFB, Fairfield	74*	33*	5	130
Vandenberg AFB, Lompoc	72*	32*	5	130
San Diego	64*	29*	0	0
Pasadena	72*	32*	0	0
Long Beach	72*	32*	0	0
San Francisco	85	38	5	130
Oakland	85	38	5	130
Mare Island	84	38	5	130
Sacramento	107	48	5	130
Stockton	92	41	5	130
China Lake	70*	31*	5	130
COLORADO:				
Lowry AFB, Denver	70*	31*	60	1500
Denver	70*	31*	60	1500
CONNECTICUT:				
New London	81	36	35	890
New Haven	81	36	35	890

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
DELAWARE:				
Dover AFB, Dover	93	42	20	510
Lewes	115	51	20	510
FLORIDA:				
Eglin AFB, Valparaiso	127	57	5	130
Homestead AFB, Homestead	127	57	0	0
McDill AFB, Tampa	91	41	2	50
Patrick AFB, Cocoa	125	56	2	50
Jacksonville	104	46	2	50
Miami	125	56	0	0
Key West	122	55	0	0
Pensacola	127	55	2	50
Tampa	87	39	2	50
GEORGIA:				
Hunter AFB, Savannah	104	46	5	130
Robins AFB, Warner Robins	78*	35*	5	130
Turner AFB, Albany	83	37	5	130
Augusta	83	37	5	130
Atlanta	86	38	7	180
Savannah	104	46	3	75
Macon	85	38	5	130
IDAHO:				
Mountain Home AFB, Mountain Home	83	37	40	1000
ILLINOIS:				
Chanute AFB, Rantoul	93	42	35	890
Scott AFB, Belleville	82	37	35	890
Chicago	90	40	83	2100
INDIANA:				
Fort Wayne	88	39	40	1000
Indianapolis	104	46	30	760
IOWA:				
Sioux City	102	46	54	1400

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
KANSAS:				
Forbes AFB, Topeka	108	48	30	760
Schilling AFB, Salina	102	46	24	610
KENTUCKY:				
Lexington	91	41	18	460
Louisville	91	41	18	460
LOUISIANA:				
Barksdale AFB, Shreveport	67*	30*	5	130
Chennault AFB, Lake Charles	121	54	4	100
New Orleans	121	54	2	50
MAINE:				
Dow AFB, Bangor	98	44	75	1900
Loring AFB, Caribou	92	41	75	1900
Portland	99	44	65	1700
Bangor	98	44	72	1800
MARYLAND:				
Andrews AFB, Washington, DC	87	39	25	640
Baltimore	90	40	22	560
Lexington Park	104	46	22	560
MASSACHUSETTS:				
L.G. Hanscom Field, Boston	108	48	50	1300
Otis AFB, Cape Cod	121	54	50	1300
Westover AFB, Springfield	86	38	70	1800
Boston	108	48	50	1300
Springfield	86	38	70	1800
MICHIGAN:				
Kinchelow AFB, Sault Ste. Marie	97	43	65	1700
Selfridge AFB, Detroit	79*	35*	50	1300
Detroit	76*	34*	50	1300
MINNESOTA:				
Minneapolis, St. Paul IAP	90	40	75	1900
Minneapolis	90	40	75	1900
Duluth	98	44	75	1900

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
MISSISSIPPI:				
Jackson	104	46	3	75
Meridian	104	46	5	130
Gulfport	127	57	5	130
MISSOURI:				
Kansas City	89	40	28	710
St. Louis	81	36	27	690
MONTANA:				
Malmstrom AFB, Great Falls	83	37	75	1900
NEBRASKA:				
Offutt AFB, Omaha	97	43	55	1400
Omaha	97	43	55	1400
Hastings	104	46	53	1300
NEVADA:				
Nellis AFB, Las Vegas	90	40	8	200
Stead AFB, Reno	92	41	23	580
Fallon	92	41	12	300
Hawthorne	92	41	30	760
Reno	95	42	23	580
NEW HAMPSHIRE:				
Pease AFB, Portsmouth	105	47	60	1500
Portsmouth	104	46	60	1500
NEW JERSEY:				
McGuire AFB, Trenton	85	38	30	760
Atlantic City	99	44	20	510
Bayonne	84	38	30	760
NEW MEXICO:				
Cannon AFB, Clovis	78*	35*	15	380
Holloman AFB, Alamogordo	81	36	20	510
Walker AFB, Roswell	86	38	15	380
Albuquerque	99	44	17	430

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
NEW YORK:				
Griffis AFB, Rome	82	37	50	1300
Plattsburg AFB, Plattsburg	91	41	70	1800
Stewart AFB, Newburgh	88	39	45	1100
Buffalo	91	41	35	890
Albany	79*	35*	54	1400
New York	84	38	40	1000
Syracuse	82	37	56	1400
NORTH CAROLINA:				
Pope AFB, Fayetteville	74*	33*	9	230
Charlotte	90	40	8	200
Wilmington	132	59	5	130
Cape Hatteras	132	59	5	130
Cherry Point	115	51	5	130
Camp LeJeune	115	51	5	130
NORTH DAKOTA:				
Grand Forks AFB, Grand Forks	99	44	25	640
Minot AFB, Minot	99	44	15	380
OHIO:				
Wright-Patterson AFB, Dayton	92	41	15	380
Columbus	92	41	15	380
Cincinnati	92	41	10	250
OKLAHOMA:				
Tinker AFB, Oklahoma City	92	41	20	510
OREGON:				
Portland Int. Airport	115	51	6	150
Portland	115	51	6	150
PENNSYLVANIA:				
Olmstead AFB, Harrisburg	72*	32*	35	890
Harrisburg	85	38	30	760
Pittsburgh	83	37	38	970
Philadelphia	81	36	30	760
RHODE ISLAND:				
Providence	114	51	45	1100

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
SOUTH CAROLINA:				
Parris Island	120	54	6	150
Charleston	122	55	3	75
SOUTH DAKOTA:				
Ellsworth AFB, Rapid City	106	47	55	1400
TENNESSEE:				
Sewart AFB, Smyrna	95	42	10	250
Memphis	92	41	10	250
TEXAS:				
Amarillo AFB, Amarillo	120	54	20	510
Bergstrom AFB, Austin	86	38	4	100
Biggs AFB, El Paso	92	41	6	150
Carswell AFB, Ft. Worth	85	38	12	300
Dyess AFB, Abilene	100	45	10	250
Ellington AFB, Houston	90	40	3	75
Kelley AFB, San Antonio	88	39	4	100
Kingsville NAS, Kingsville	105	47	4	100
Reese AFB, Lubbock	86	38	15	380
Sheppard AFB, Wichita Falls	85	38	15	380
Corpus Christi	115	51	2	50
El Paso	92	41	6	150
Fort Worth	79*	35*	10	250
Galveston	101	45	3	75
Houston	92	41	3	75
San Antonio	75*	34*	4	100
Amarillo	120	54	20	510
UTAH:				
Hill AFB, Ogden	93	42	35	890
Salt Lake City	88	39	35	890
VERMONT:				
Burlington	91	41	35	890
VIRGINIA:				
Langley AFB, Hampton	109	49	6	150
Newport News	106	47	10	250
Norfolk	106	47	10	250

Table 12 (Continued)
Wind and Frost Penetration Data for Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
VIRGINIA (continued):				
Richmond	88	39	14	360
Virginia Beach Coast	115	51	14	360
Yorktown	100	45	14	360
WASHINGTON:				
Fairchild AFB, Spokane	65*	29*	91	2300
Larson AFB, Moses Lake	72*	32*	35	890
McChord AFB, Tacoma	83	37	10	250
Bremerton	83	37	8	200
Seattle	83	37	8	200
Spokane	91	41	30	760
Pasco	75*	34*	25	640
Tacoma	83	37	8	200
WEST VIRGINIA:				
Charleston	81	36	30	760
WISCONSIN:				
Truax Field, Madison	114	51	50	1300
Milwaukee	112	50	54	1400
Green Bay	100	45	54	1400
WYOMING:				
Francis E. Warren AFB, Cheyenne	99	44	70	1800
WASHINGTON, DC	92	41	20	510

* Use a minimum of 80 mph [36 m/s] for design.

Table 13
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
AFRICA:				
Libya:				
Wheelus AB	84	38	0	0
Morocco:				
Casablanca	84	38	0	0
Port Lyautey NAS	84	38	0	0
ASIA:				
India:				
Bombay	85	38	0	0
Calcutta	106	47	0	0
Madras	86	38	0	0
New Delhi	85	38	0	0
Japan:				
Itazuke AB	92	41	6	150
Johnson AB	104	46	6	150
Misawa AB	94	42	18	460
Tachikawa AB	98	44	6	150
Tokyo	98	44	6	150
Wakkanai	115	51	36	910
Korea:				
Kimpo AB	72*	32*	30	760
Seoul	72*	32*	30	760
Uijongbu	59*	26*	36	910
Pakistan:				
Peshawar	82	37	6	150
Saudi Arabia:				
Bahrain Island	81	36	0	0
Dhahran AB	81	36	0	0
Taiwan:				
Tainan	120	54	0	0
Taipei	130	58	0	0

Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
ASIA (continued):				
Thailand:				
Chiang Mai	78*	35*	0	0
Bangkok	78*	35*	0	0
Sattahip	85	28	0	0
Udonthani	63*	28*	0	0
Turkey:				
Ankara	92	41	24	610
Karamursel	105	47	12	300
Vietnam:				
Da Nang	120	54	0	0
Nha Trang	94	42	0	0
Saigon	94	42	0	0
ATLANTIC OCEAN AREA:				
Ascension Island	62*	28*	0	0
Azores:				
Lajes Field	117	52	0	0
Bermuda	127	57	0	0
CARIBBEAN SEA:				
Bahama Islands:				
Eleuthera Island	138	62	0	0
Grand Bahama Island	138	62	0	0
Grand Turk Island	150	67	0	0
Great Exuma Island	138	62	0	0
Cuba:				
Guantanamo NAS	90	40	0	0
Leeward Islands:				
Antigua Island	138	62	0	0
Puerto Rico:				
Ramey AFB	93	42	0	0
San Juan and Sabana Seca	116	52	0	0
Vieques Isl./Roosevelt Rds	138	62	0	0

Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
CARIBBEAN SEA (continued):				
Trinidad Island:				
Port of Spain	55*	25*	0	0
Trinidad NS	55*	25*	0	0
CENTRAL AMERICA:				
Canal Zone:				
Albrook AFB	62*	28*	0	0
Balboa	62*	28*	0	0
Coco Solo	52*	23*	0	0
Colon	58*	23*	0	0
Cristobal	58*	28*	0	0
France AFB	58*	28*	0	0
EUROPE:				
England:				
Birmingham	83	37	12	300
London	88	39	12	300
Mildenhall AB	97	43	12	300
Plymouth	87	39	12	300
Sculthorpe AB	92	41	12	300
Southport	97	43	12	300
South Shields	92	41	12	300
Spurn Head	92	41	12	300
France:				
Nancy	81	36	18	460
Paris/LeBourget	94	42	18	460
Rennes	102	46	18	460
Vichy	114	51	24	610
Germany:				
Bremen	79*	35*	30	760
Munich-Reim	91	41	36	910
Rhein-Main AB	79*	35*	30	760
Stuttgart AB	84	38*	36	910
Greece:				
Athens	86	38*	0	0
Souda Bay	80	36	0	0

Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
EUROPE (continued):				
Iceland:				
Keflavik	115	51	24	610
Thorshofn	136	61	36	910
Italy:				
Aviano AB	74*	33*	18	460
Brindisi	102	46	6	150
La Maddalena	80	36		
Sigonella-Catania	90	40		
Scotland:				
Aberdeen	84	38	12	300
Edinburgh	92	41	12	300
Edzell	84	38	12	300
Glasgow/Renfrew Airfield	92	41	12	300
Lerwick, Shetland Islands	104	46	18	460
Londonderry	124	55	12	300
Prestwick	93	42	12	300
Stornoway	112	50	12	300
Thurso	98	44	12	300
Spain:				
Madrid	77*	34*	6	150
Rota	87	39	0	0
San Pablo	109	49	6	150
Zaragoza	109	49	6	150
NORTH AMERICA:				
Alaska:				
Adak, Aleutian Islands	124	55	24	610
Anchorage	97	43	60	1500
Annette	94	42	24	610
Attu	178	80	24	610
Barrow	109	49	**	**
Bethel	94	42	60	1500
Cold Bay	110	49	36	910
Cordova	94	42	48	1200
Eielson AFB	75*	34*	60	1500
Elmendorf AFB	93	42	60	1500
Fairbanks	75*	34*	60	1500

Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind gust (peak velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
NORTH AMERICA (continued):				
Alaska (continued):				
Gambell	130	58	48	1200
Juneau	92	41	36	910
King Salmon	115	51	60	1500
Kodiak	116	52	48	1200
Kotzebue	122	55	**	**
McGrath	85	38	84	2100
Middleton Island AFS	125	56	48	1200
Nikolski, Umnak Island	129	58	36	910
Nome	120	54	**	**
Northeast Cape AFS, St. Lawrence Island	133	59	48	1200
Shemya Island	178	80	24	610
St. Paul Island	105	47	36	910
Umiat	112	50	**	**
Wales	105	47	**	**
Yakutat	99	44	36	910
Canada:				
Argentia NAS, Newfoundland	107	48	36	910
Churchill, Manitoba	100	45	**	**
Cold Lake, Alberta	75*	34*	72	1800
Edmonton, Alberta	78*	35*	60	1500
E. Harmon AFB, Newfoundland	105	47	60	1500
Fort William, Ontario	75*	34*	60	1500
Frobisher, N.W.T.	100	45	**	**
Goose Airport, Newfoundland	83	37	60	1500
Ottawa, Ontario	84	38	48	1200
St. John's, Newfoundland	106	47	36	910
Toronto, Ontario	84	38	36	910
Winnipeg, Manitoba	76*	34*	60	1500
Greenland:				
Narsarssuak AB	129	58	60	1500
Simiutak AB	154	69	60	1500
Sondrestrom AB	112	50	**	**
Thule AB	132	59	**	**

Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
PACIFIC OCEAN AREA:				
Australia:				
H.E. Holt, NW Cape	130	58	0	0
Caroline Islands:				
Koror, Palau Islands	95	42	0	0
Ponape	109	49	0	0
Hawaii:				
Barber's Point	67*	30*	0	0
Hickam AFB	79*	35*	0	0
Kaneohe Bay	84	38	0	0
Wheeler AFB	63*	28*	0	0
Hawaiian Islands:				
Hawaii	*	*	0	0
Kahoolawe	*	*	0	0
Kauai	*	*	0	0
Lanai	*	*	0	0
Maui	*	*	0	0
Molokai	*	*	0	0
Niihau	*	*	0	0
Oahu	*	*	0	0
Johnston Island	72*	32*	0	0
Mariana Islands:				
Agana, Guam	155	69	0	0
Andersen AFB, Guam	155	69	0	0
Kwajalein	104	46	0	0
Saipan	150	67	0	0
Tinian	150	67	0	0
Marcus Island	150	67	0	0
Midway Island	87	39	0	0
Okinawa:				
Kadena AB	184	82	0	0
Naha AB	178	80	0	0

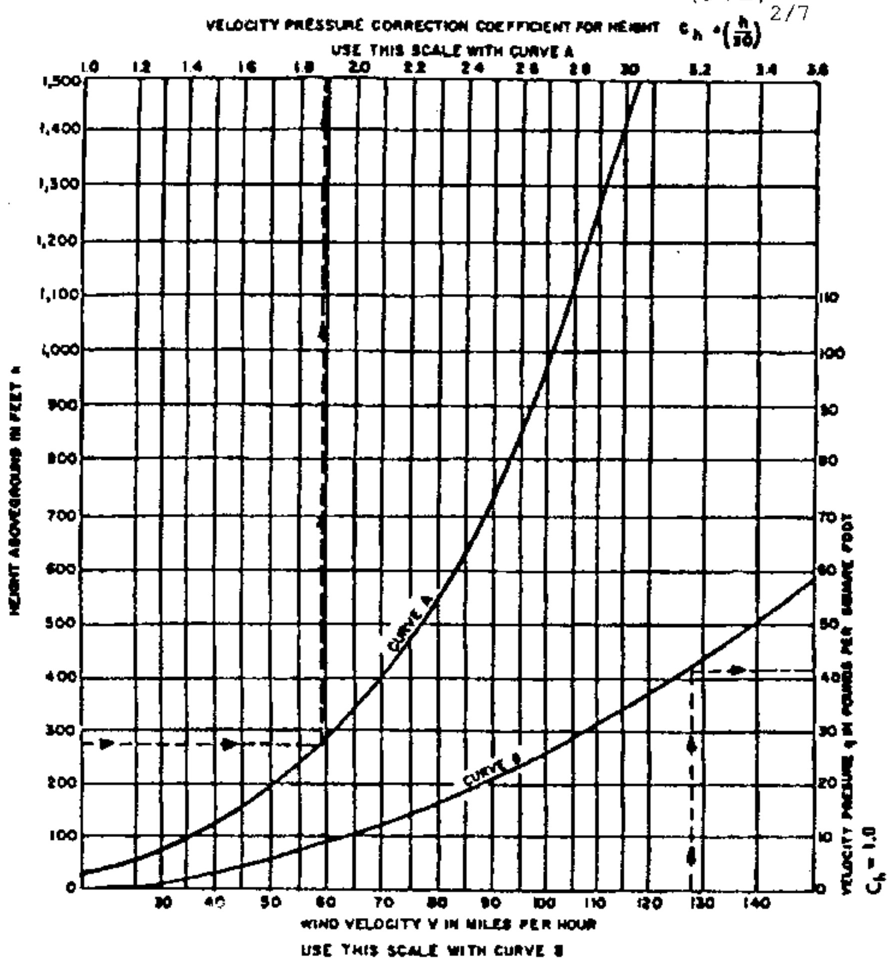
Table 13 (Continued)
Wind and Frost Penetration Data for Locations
Other Than the Contiguous States

Location	Wind (peak gust velocity) (mph)	[m/s]	Frost Penetration (inches)	[mm]
PACIFIC OCEAN AREA (continued):				
Philippine Islands:				
Clark AFB	87	39	0	0
Sangley Point	68*	30*	0	0
Subic Bay	77*	34*	0	0
Samoa Islands:				
Apia, Upolu Island	147	66	0	0
Tutuila, Tutuila Island	147	66	0	0
Volcano Islands:				
Iwo Jima AB	206	92	0	0
Wake Island	86	38	0	0

* Use a minimum of 80 mph [36 m/s] for design.
** Permafrost

$$C = \left(\frac{h}{9.1}\right)^{2/7} \quad \text{[h in meters]}$$

$$C_h = \left(\frac{h}{30}\right)^{2/7} \quad \text{[h in feet]}$$



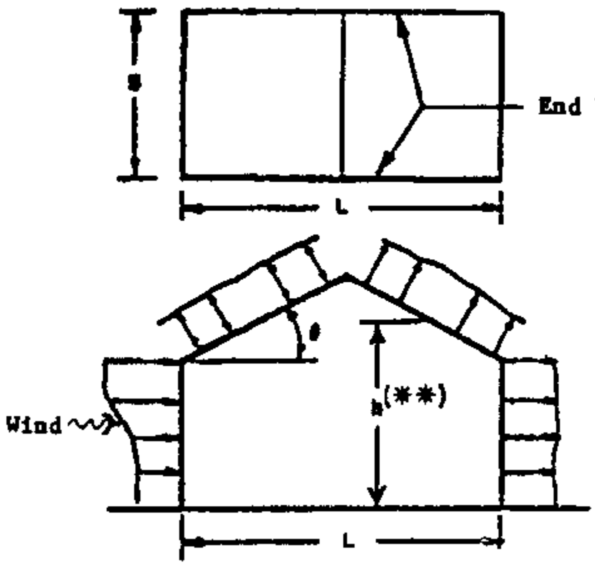
Multiply values in "pounds per square foot" by 0.04788 to get values in "kPa"

Multiply values in "feet" by 0.3048 to get values in "meters"

Multiply values in "miles per hour" by 0.44704 to get values in "meters per second"

Figure 13
Velocity Pressure and Variation of Velocity Pressure
With Height Aboveground

Table 14
External Pressure Coefficient (C_S) for Average Loads on Main Wind - Force Resisting System



WALL PRESSURE COEFFICIENTS

SURFACE	L/B	C_p
WINDWARD WALL	ALL VALUES	0.8
LEEWARD WALL	0-1 2 ≥4	-0.5 -0.3 -0.2
END WALLS	ALL VALUES	-0.7

ROOF PRESSURE COEFFICIENTS C_p

Wind Direction	h/L	Windward							Leeward
		Angle θ Degrees							
		0	10-15	20	30	40	50	60	
Normal to Ridge	≤0.3 0.5 1.0 ≥1.5	-0.7 -0.7 -0.7 -0.7	0.2* -0.9 -0.9 -0.9	0.2 -0.75 -0.75 -0.9	0.3 -0.2 -0.2 -0.9	0.4 0.3 0.3 -0.35	0.5 0.5 0.5 -0.21	0.01θ 0.01θ 0.01θ 0.01θ	-0.7 for all values of h/L
Parallel to Ridge	h/B or h/L <2.5				-0.7				-0.7
	h/B or h/L >2.5				-0.8				-0.8

Table 14 (Continued)
External Pressure Coefficient (C_p) for Average Loads
on Main Wind - Force Resisting System

* The coefficient of -0.9 shall be used for roofs rising from ground level. Roofs with other slopes and/or buildings with other h/L values are to be designed using the same pressure values whether the roof rises from the ground or the roof begins aboveground.

** h: Mean roof height in feet except that eave height may be used for θ < 10 degrees.

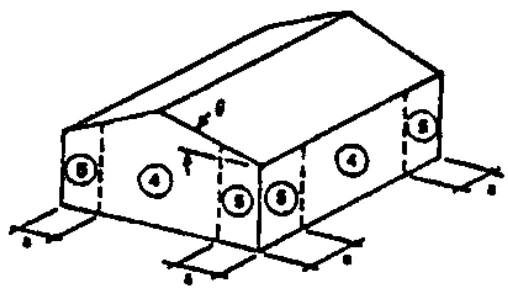
Notes:

1. See Table 19 for arched roof, Tables 15 and 16 for components and cladding and Table 18 for internal pressures.

2. + and - signs signify pressure acting toward and away from the surfaces, respectively.

3. Linear interpolation may be used for values of θ and h/L ratios other than those shown.

Table 15
External Pressure Coefficient (C_p) for Loads on Building Components and Cladding for Buildings With Mean Roof Height $h \leq 60$ ft. [$h \leq 18$ m] - Walls



1. **Notes apply to both Table 15 and Table 16.**

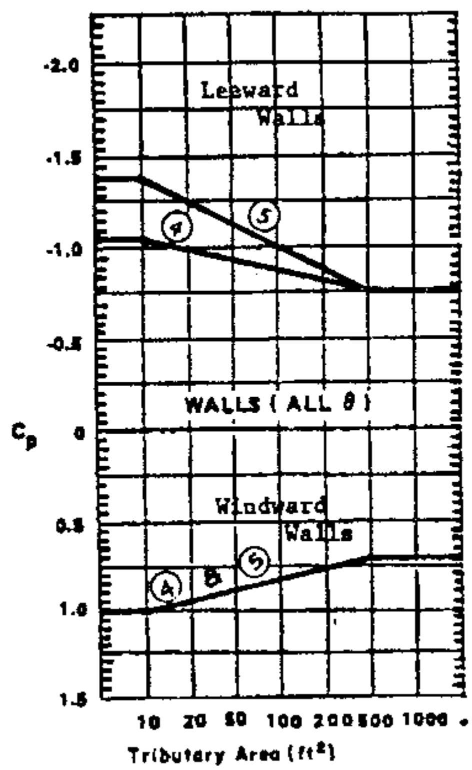
2. **Notations:**

   a = 10% of minimum width or 0.4h, whichever is smaller, but not less than 4% of minimum width or 3 ft. [0.9 m]

   + and - signs signify pressures acting toward and away from surfaces respectively.

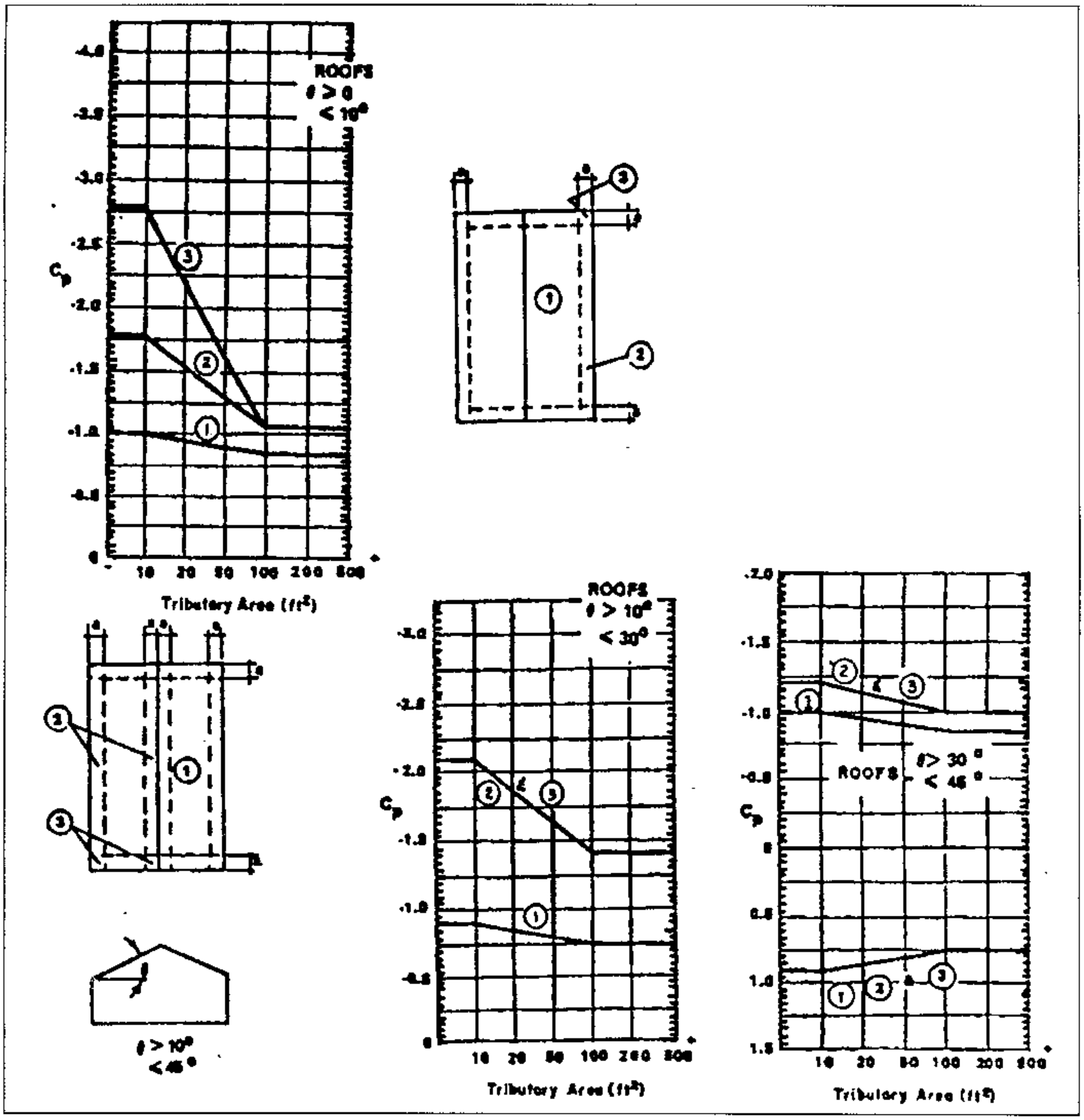
3. **When θ ≤ 10°, C_p may be reduced by 10%.**

4. **Tributary area for a component is surface area that would be supported by the component to transmit the wind loads and is <u>not</u> the same as influence area considered for live loads.**



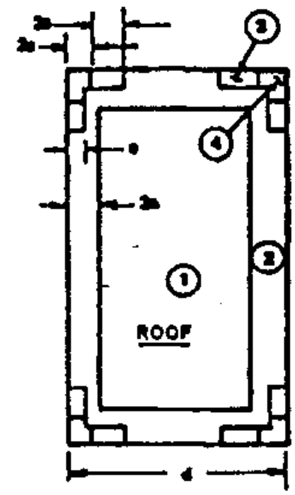
Multiply "sq. ft." by 0.0929 to get values in "sq. m"

Table 16
External Pressure Coefficient (C_p) for Loads on Building Components and Cladding for Buildings With Mean Roof Height $h \leq 60$ ft. [$h \leq 18$ m] - Roofs



Multiply "sq. ft." by 0.0929 to get values in "sq. m"

Table 17
External Pressure Coefficient (C_p) for Loads on Building Components and Cladding for Buildings With Mean Roof Height h > 60 ft. [h > 18 m]- Roofs and Walls]



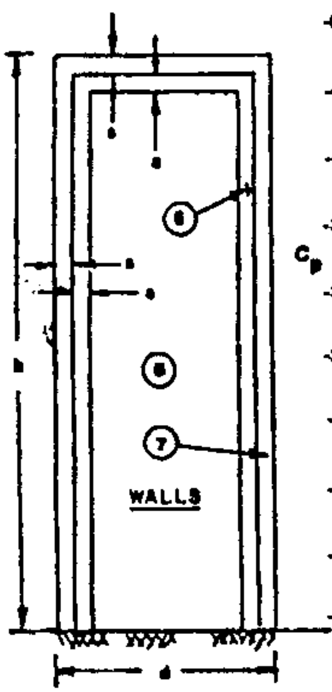
NOTES:

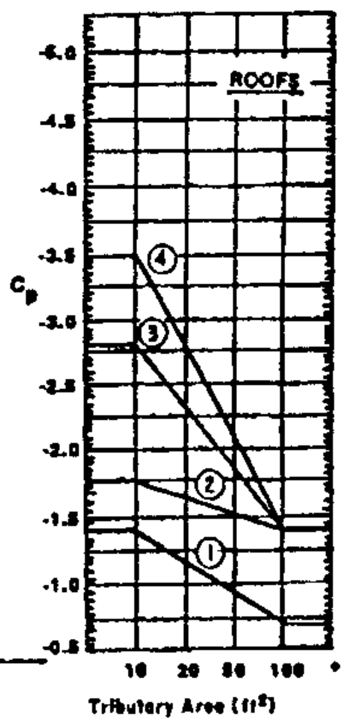
1. If a parapet is provided around the roof perimeter, Zones 3 & 4 may be treated as Zone 2. Minimum parapet height required to realize these reduced pressures is 24 inches.

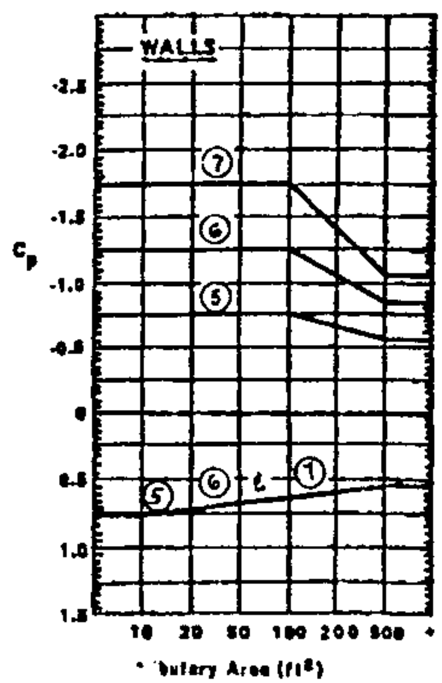
2. For roofs with slope > 10°, use c_p from Tables 15 & 16.

3. Notations -- a: 5% of minimum width or 0.5h, whichever is smaller; + and - signs signify pressures acting toward and away from the surfaces, respectively.

4. Tributary area for a component is surface area that would be supported by the component to transmit the wind loads, and is not the same as influence considered for live loads.







Multiply "sq. ft." by 0.0929 to get values in "sq. m"

Table 18
Internal Pressure Coefficients for Buildings*

Condition	c_p
1. Percentage of opening area in one wall exceeds that of all other walls by 10% or more, and opening area in all other walls do not exceed 20% of respective wall areas	+0.50 -0.17
2. All other cases	+/- 0.17

* Internal pressures are additive to external pressures in accordance with $q_{total} = q_{external} + (-q_{internal})$

Table 19
External Pressure Coefficients for Arched Roofs

	Rise-to-Span Ratio, r	Windward Quarter	Center Half	Leeward Quarter
Roof on elevated structure	0.0 < r < 0.2 0.2 < / = r < / = 0.3 0.3 < / = r < /= 0.6	- 0.9 (1.5 r - 0.3)* (2.75r - 0.7)	(-0.7 - r) (-0.7 - r) (-0.7 - r)	-0.50 -0.50 -0.50
Roof Springing at ground level	0.0 < r < / = 0.6	1.4	(-0.7 - r)	-0.50

* When the rise-to-span ratio is (0.2 < / = r < / = 0.3), alternative coefficients given by (6r - 2.1) also shall be used for the windward quarter.

Table 19 (Continued)
External Pressure Coefficients for Arched Roofs

Notes:

1. Values shown are for average loads on main wind-force resisting system.
2. + and - signs signify pressure acting toward and away from the surface respectively.
3. For components and cladding:
    a) At roof perimeter, use external pressure coefficients in Tables 15 and 16, with 0 based on spring line slope.
    b) In remaining roof areas, use external pressure coefficients of this table, multiplied by 1.2.

Table 20
Pressure Coefficients and Location of Center of Pressure for Flat Roofs Over Open Buildings and Other Structures

Pressure Coefficient							
	B/L						
[theta]	1/5	1/3	1/2	1	2	3	5
10 deg	0.2	0.25	0.3	0.45	0.55	0.7	0.75
15 deg	0.35	0.45	0.5	0.7	0.85	0.9	0.85
20 deg	0.5	0.6	0.75	0.9	1.0	0.95	0.9
25 deg	0.7	0.8	0.95	1.15	1.1	1.05	0.95
30 deg	0.9	1.0	1.2	1.3	1.2	1.1	1.0

Location of Center of Pressure, X/L			
	B/L		
[theta]	1/5 to 1/2	1	2 to 5
10 deg	0.35	0.3	0.3
15 deg	0.35	0.3	0.3
20 deg	0.35	0.3	0.3
25 deg	0.35	0.35	0.4
30 deg	0.35	0.4	0.45

Notes:
1. Wind forces act normal to surface and may be directed inward or outward.
2. The wind shall be assumed to deviate by +/- 10 degrees from horizontal.
3. Notation:
   [theta]: Angle of plane roof from horizontal.
   X: Distance to center of pressure from windward edge of roof.
   B: Building plan dimension, perpendicular to wind direction.
   L: Building plan dimension, parallel to wind direction.

Table 21
Pressure Coefficients for Chimneys, Tanks, and Similar Structures

Shape	Type of Surface	h/D		
		1	7	25
Square (wind normal to a face)	All	1.3	1.4	2.0
Square (wind along diagonal)	All	1.0	1.1	1.5
Hexagonal or octagonal D [SQRT] q > 2.5 [170]	All	1.0	1.2	1.4
Round D [SQRT] q > 2.5 [170]	Moderately smooth	0.5	0.6	0.7
	Rough (D'/D=0.02)	0.7	0.8	0.9
	Very rough (D'/D=0.8)	0.8	1.0	1.2
Round D [SQRT] q ≤ 2.5 [170]	All	0.7	0.8	1.2

Notes:

1. The design wind force shall be calculated based on the area of the structure projected on a plane normal to the wind direction. The force shall be assumed to act parallel to the wind direction.

2. Linear interpolation may be used for h/D values other than shown.

3. Notation:
   - D: Diameter or least horizontal dimension in feet [mm]
   - D': Depth of protruding elements such as ribs and spoilers in feet [mm]
   - h: Height of structure in feet [mm]
   - q: From Equations (9)in feet [and (8) in kPa]

Table 22
Pressure Coefficients for Solid Signs

At Ground Level							
M/N	< / =3	5	8	10	20	30	> / = 40
C_f	1.2	1.3	1.4	1.5	1.75	1.85	2.0
Above Ground Level							
M/N	< / = 6	10	16	20	40	60	> / = 80
C_f	1.2	1.3	1.4	1.5	1.75	1.85	2.0

Notes:

1. Signs with openings of less than 30% of gross area shall be considered solid signs.

2. Signs for which the distance from ground to bottom edge is less than 0.25 times the vertical dimension shall be considered to be at ground level.

3. To allow for both normal and oblique wind directions, two cases shall be considered:

   a) Normal wind actions at geometric center, and
   b) The same, total normal force as in Note a) acting at the level of the geometric center, but at a distance from windward edge of 0.3 times the horizontal dimension of the sign.

4. Notation:
   M: Larger dimension of sign in feet [mm]
   N: Smaller dimension of sign in feet [mm]

Table 23
Pressure Coefficients for Open Signs and
Latticed Frameworks

Ratio of Solid Area to Gross Area (ε)	Flat-Sided Members	Rounded Members	
		D[SQRT]q ≤ 2.5[170]	D[SQRT]q > 2.5[170]
Less than 0.1	2.0	1.2	0.8
0.1 to 0.29	1.8	1.3	0.9
0.3. to 0.7	1.6	1.5	1.1

Notes:

1. Signs with openings of 30 percent or more of gross area are classified as open signs.

2. The design wind forces shall be calculated based on the area of exposed members and elements projected on a plane normal to the wind direction. Forces shall be assumed to act parallel to the wind direction.

3. Notation:
   D: Diameter of a typical round member in feet [mm]
   q: From Equations (9) in feet [and (8) in kPa]

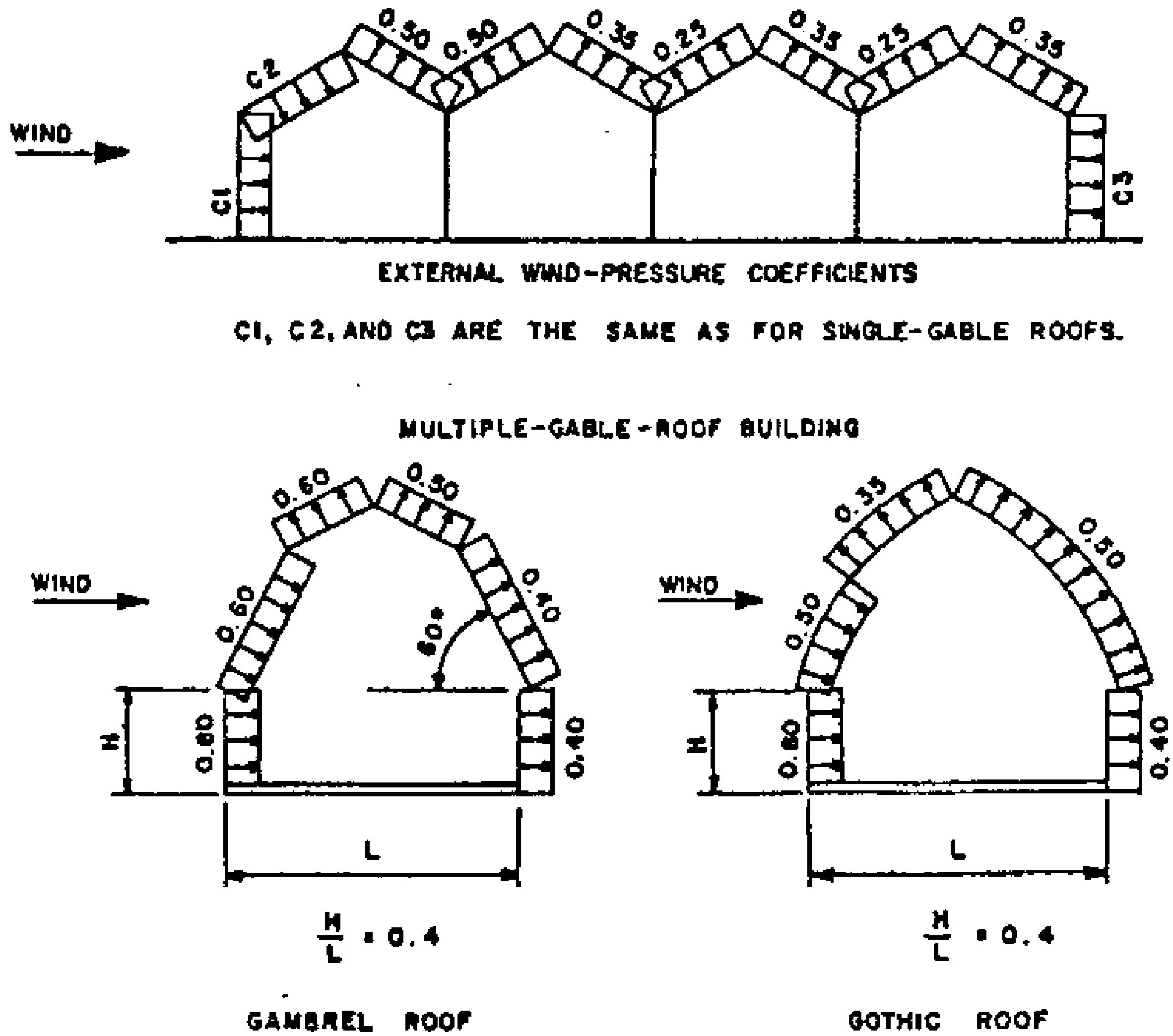
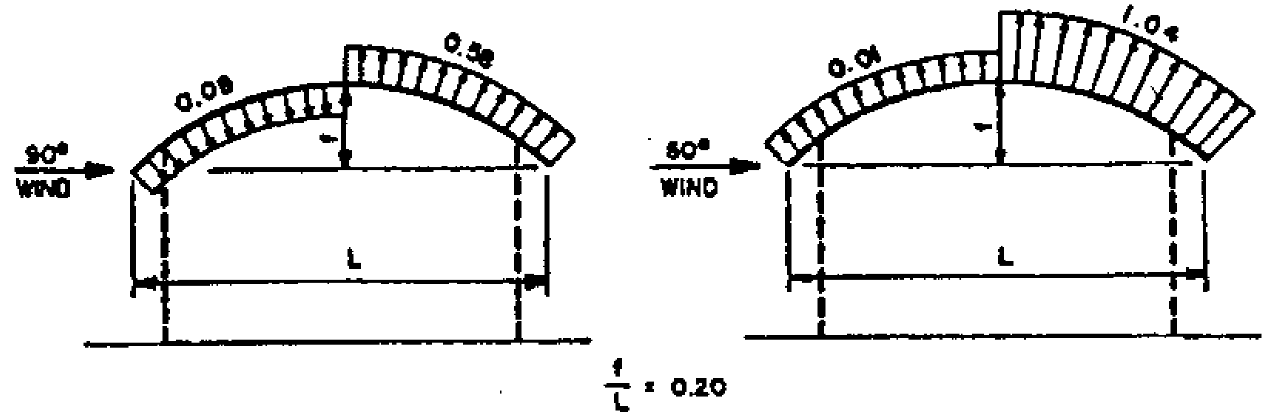
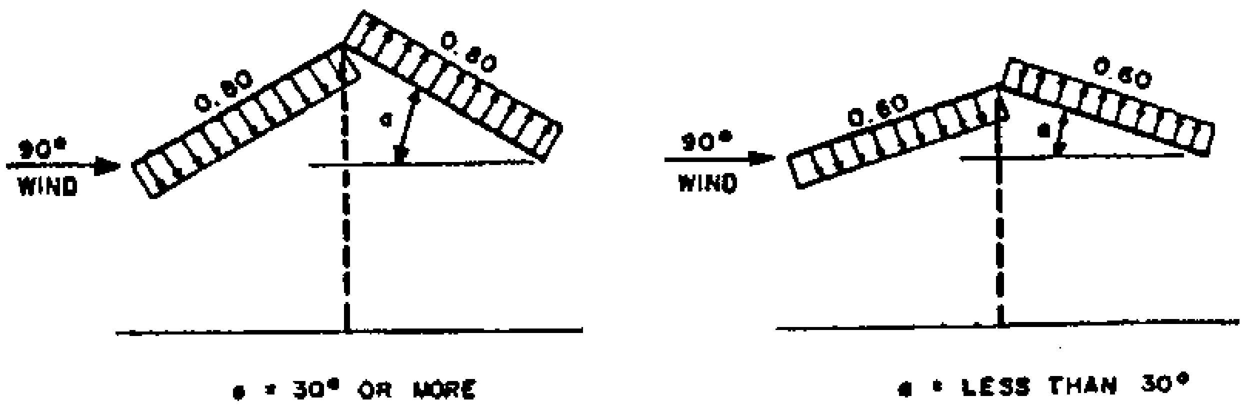


Figure 14
Pressure Coefficients for Compound Roof Shapes

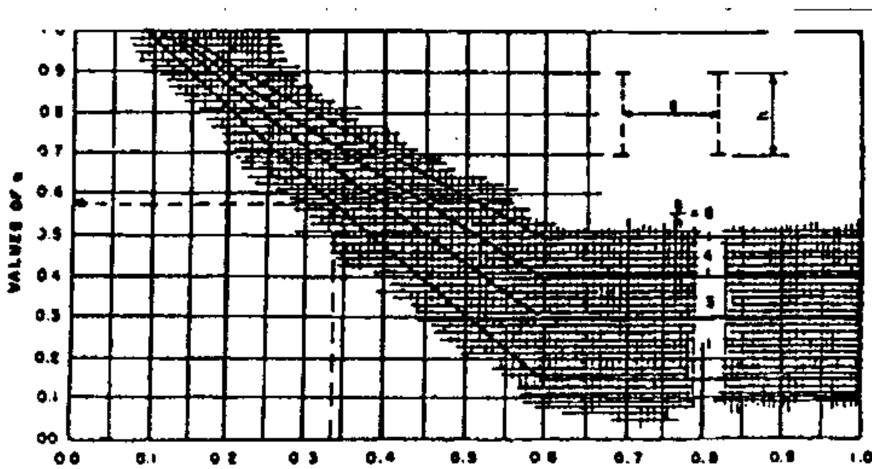


EXTERNAL PLUS INTERNAL WIND-PRESSURE COEFFICIENTS
FOR CURVED ROOFS ON OPEN SHEDS



EXTERNAL PLUS INTERNAL WIND-PRESSURE COEFFICIENTS
FOR GABLE ROOFS ON OPEN SHEDS

Figure 15
Pressure Coefficients for Open Sheds



VALUES OF $\frac{A_p}{A_g}$

A_p = Total projected area of members on one side of the structure.

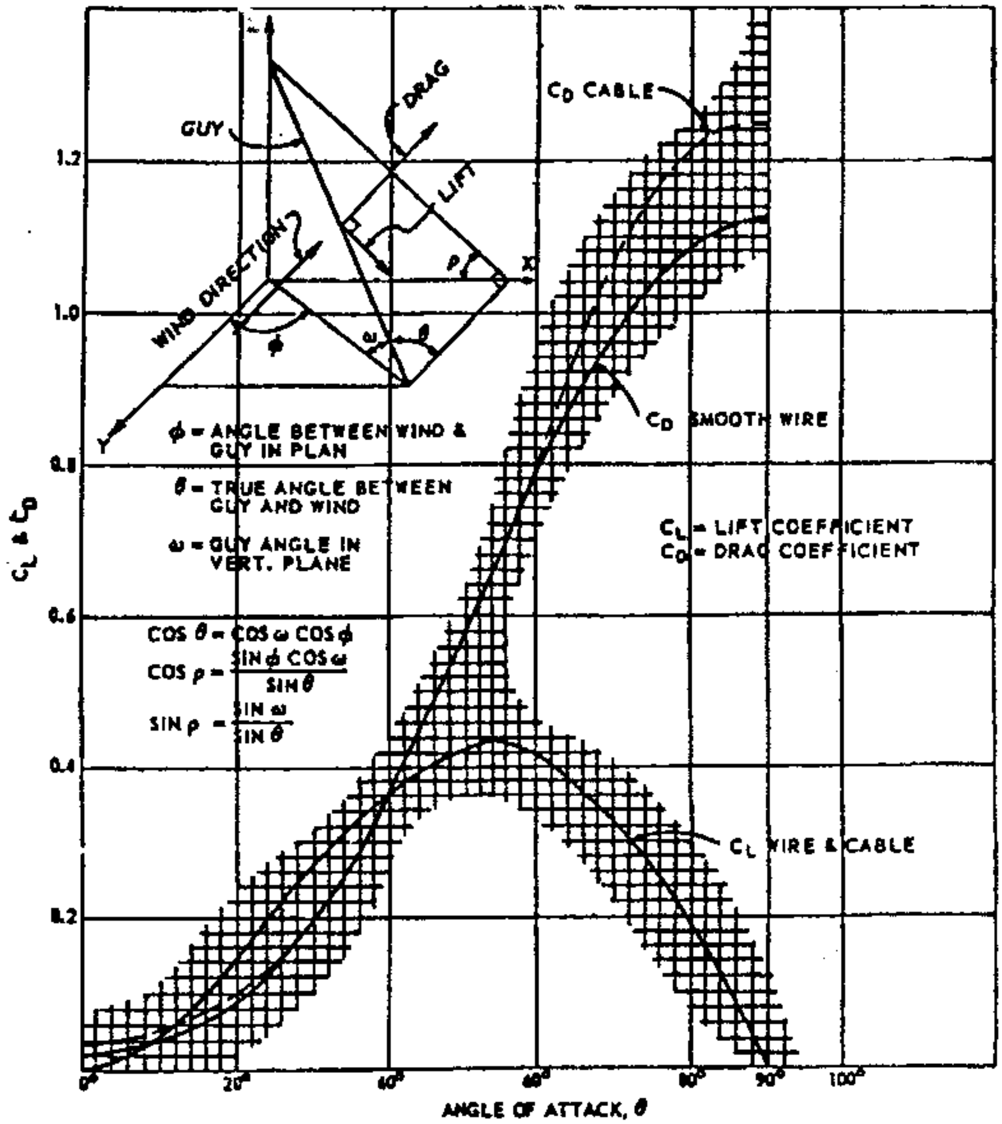
A_g = Total area within the limiting lines for one side of the structure.

n In the diagram applies to trusses and latticed members except triangular towers.

Type of Structures	Pressure Coefficient on Projected Area
Double parallel solid girder	1.10
Double parallel trusses and Double parallel latticed members	1.6 (1 + n)
Girders and trusses with m parallel members where m is more than 2	1.5 + (m-2) 0.5
Towers	
Square cross section, wind on face → □	1.6 (1 + n)
Square cross section, wind on corner → □	1.92 (1 + n)
Triangular cross section, wind on face → △	2.28
Triangular cross section, wind on corner → △	1.93

Notes:
1. For single, open-lattice frameworks, see Table 23.
2. Use 2/3 of above values for round members.

Figure 16
Pressure Coefficients for Structures Having Multiple Presentments



Drag and Lift Coefficients for Wire and Cable

DRAG AND LIFT FORCES

DRAG = 2.133 (cdv^2) C_D x 10^{-7} Kips [= 6.132 (cdv^2) C_D x 10^{-7} kN]
LIFT = 2.133 (cdv^2) C_L x 10^{-7} Kips [= 6.132 (cdv^2) C_L x 10^{-7} kN]

Where c = chord length of cable in feet [m]
d = diameter of cable in inches [mm]
v = wind velocity in mph [m/s] (usually taken as velocity at mid-height of cable)

Note: LIFT for leeward cable is positive acting upward.

Figure 17
Wind Forces on Guy Wires and Cables

7.4 Eaves and Cornices. Design overhanging eaves and cornices for an upward pressure of twice the external pressure.

7.5 Class A Structures. Criteria on wind loads and their effect on bridge structures are contained in the AASHTO Standard HB-13, Standard Specifications for Highway Bridges and the AREA Manual for Railway Engineering.

7.6 Special Conditions

7.6.1 Wind on Berthed Vessel. Refer to DM-26 series.

7.6.2 Prefabricated Buildings of Standard Manufacture. Nothing in this handbook precludes acquisition of standard prefabricated buildings. Design such buildings, however, for adequacy under loading combinations specified in this handbook (e.g., snow, wind, and seismic).

7.6.3 Mobile Home Tie-Downs

a) Hurricanes in the Gulf Coast area have caused extensive damage to mobile homes. Many of these units appear not to have employed tie-down devices. Although some had rods which anchored the chassis to the foundation, internal connections in the superstructure were unable to resist the wind forces. It is believed that over-the-roof ties would have prevented most of this loss.

b) Similar damage resulted from Hurricane Camille (1969) and other major storms. To reduce damage due to high winds, mobile homes should be adequately anchored. Over-the-roof anchorage appears to be preferable. If anchor connections are at the first floor level, the units should be analyzed to determine the adequacy of the floor-to-wall and floor-to-roof connections.

7.6.4 Wind-Induced Vibrations

a) In general, tanks, towers, and stacks are drag-sensitive structures. Consequently, in the design of such structures, investigate the effects of wind-induced vibrations. For further information, refer to American Society of Civil Engineers (ASCE), Wind-Induced Vibrations in Antenna Members.

b) Failure of standard types of structural members has been attributed to wind-induced vibrations. Little information is available on vibrations in members of I and WF shapes. However, to avoid vortex-shedding phenomenon, rectangular beams and girders should have a width (parallel to wind direction)-to-depth (perpendicular to wind direction) ratio of less than 0.75 or greater than 3.5.

7.6.5 Cranes and Derricks. For non-operating conditions, design cranes and derricks for external wind pressures as described above. For criteria for operating conditions, refer to DM-38.01.

Section 8: EARTHQUAKE FORCES

8.1 Class A Structures. The provisions of the AASHTO design standard apply.

8.2 Class B Structures. Design buildings in seismic areas in accordance with NAVFAC P-355, Seismic Design for Buildings. Design essential buildings according to NAVFAC P-355.1, Seismic Design Guidelines for Essential Buildings. In no case shall the requirements be less than those in NAVFAC P-355.

8.2.1 Serviceability. The criteria in NAVFAC P-355 are intended to provide for reasonable life safety. However, structures designed to this criteria may sustain appreciable damage if exposed to a large earthquake (site acceleration .3g or greater). Designs should incorporate materials and details of construction to minimize damage that would result from strong ground motion and the corresponding destruction and displacement in the structure. If there is a stated requirement for the structure to remain functional after a large earthquake, devote additional attention to the design (refer to NAVFAC P-355.1).

8.2.2 Parts or Components. For forces on parts or components of a structure, use the value computed in accordance with NAVFAC P-355.

8.2.3 Earthquake Zones. Earthquake zones are indicated in NAVFAC P-355.

8.2.4 Existing Structures. Existing buildings (except steel braced frames and special moment resisting frames) are considered seismically adequate if designed and constructed in accordance with NAVFAC P-355 (1982 edition or later). Other buildings are seismically adequate if they meet the Federal Emergency Management Agency (FEMA) 178, NEHRP Handbook for the Seismic Evaluation of Existing Buildings, June 1992, evaluation. Buildings are normally evaluated for 85 percent of the demand for new construction. Essential buildings are designed to provide increased performance capability. (Guidelines are available from the Naval Facilities Engineering Service Center (NFESC), Code ESCOOCE9.)

8.3 Class C Structures. Criteria relating to earthquake forces on piers and wharves are presented in MIL-HDBK-1025/1. Criteria relating to other types of Class C structures await development. In the interim, criteria for Class B structures should be used to the extent applicable.

Section 9: OTHER LOADS

9.1 Earth Pressures and Foundation Structure Loads. Standards for determining earth pressures and foundation structure loads are contained in NAVFAC DM-7.01, Soil Mechanics, and DM-7.02, Foundations and Earth Structures.

9.2 Fluid Pressures and Forces. Consider the following fluid pressures and forces in structural design.

9.2.1 Hydrostatic Pressure. Compute as the product of liquid height times density.

9.2.2 Wave Forces. Wave force criteria are described in MIL-HDBK-1025/1, MIL-HDBK-1025/4, MIL-HDBK-1025/6, and DM-26 Series.

9.2.3 Current Forces. Current force criteria are contained in MIL-HDBK-1025/1, MIL-HDBK-1025/4, MIL-HDBK-1025/6, and DM-26 Series.

9.3 Centrifugal Forces. Refer to AASHTO and AREA design standards.

9.4 Traction. Refer to Section 4.

9.5 Thermal Forces. Refer to Section 10, as well. Provide for stresses or movements resulting from variations in temperature. On cable structures, consider changes in cable sag and tension. Determine the rises and falls in the temperature for the localities in which structures are built. Establish these rises and falls from assumed temperatures at times of erection. Consider the lags between air temperatures and interior temperatures of massive concrete members or structures.

9.5.1 Temperature Ranges. Except as indicated in the AASHTO design standard, the ranges of temperature for exterior, exposed elements, generally, are:

Structure	Climate (degrees F) [degrees C]	
	Moderate	Cold
Metal	0 to 120 [-18 to 49]	-30 to 120 [-34 to 49]
Concrete:		
Rise	30 [17]	35 [19]
Fall	-40 [-22]	-45 [-25]

The design of framing within enclosed buildings seldom need consider the forces and/or movements resulting from a variation in temperature of more than 30 degrees F [17 degrees C] to 40 degrees F [22 degrees C]. The effects of such forces and/or movements often are neglected in the design of buildings having plan dimensions of 250 feet [76 m] or less, although movements of 1/4 to 3/8 inch [6 to 10 mm] can develop and may be important for buildings constructed with long bearing walls, parallel to direction of movement.

9.5.2 Piping. To accommodate changes in length due to thermal variations, pipes frequently are held at a single point. Include the thermal loads from vertical piping in buildings in the design of support framing.

9.6 Friction Forces

9.6.1 Sliding Plates. Use 10 percent of the dead load reactions for bronze or copper-alloy sliding plates. Consult manufacturer for special systems.

9.6.2 Rockers or Rollers. Use 3 percent of the dead load reactions when employing rockers or rollers.

9.6.3 Foundations on Earth. Criteria for foundations on earth are contained in NAVFAC DM-7.01.

9.6.4 Other Bearings. Use the Mark's Standard Handbook for Mechanical Engineers, Avallona and Baumeister, 1987, for coefficients of friction. Base the forces on dead load reactions plus any applicable longtime live load reactions.

9.7 Shrinkage. Refer to Section 10.

9.7.1 Stress. Investigate arches and similar structures for stresses induced by shrinkage and rib shortening.

9.7.2 Coefficient of Shrinkage. For masonry structures, assume the minimum linear coefficient of shrinkage as 0.0002, and compute the theoretical shrinkage displacement as the product of the linear coefficient and the length of the member.

9.8 Foundation Displacement and Settlement. Refer to Section 11 also. Criteria for foundation displacement and settlement are outlined in NAVFAC DM-7.01 and DM-7.02.

9.9 Ice

9.9.1 On Antenna Supports and Transmission Line Structures. Refer to Section 6.

9.9.2 On Bridge Piers. Refer to AASHTO Standard Specifications for Highway Bridges, 1996.

9.10 Blast Loading. Refer to NAVFAC P-397, Structures to Resist the Effects of Accidental Explosions.

Section 10: COMBINATIONS OF LOADS

10.1 General. The following criteria stipulate combinations of loads (and related load factors or allowable stresses) to be considered in the design of structures and foundations. Members shall have adequate strength (and stiffness) to resist applicable combinations at applicable stresses or load factors for said combinations.

10.2 Class A Structures. The provisions of the AASHTO and AREA design standards apply.

10.3 Class B Structures. The provisions of American Concrete Institute (ACI)-318, Building Code Requirements for Reinforced Concrete, apply as follows:

10.3.1 Working Stress Design. The provisions relating to increased allowable stresses under par. 10.4.1 apply.

10.3.2 Exception for Plastic Design of Steel Frames. The provisions of Part 2 of the American Institute of Steel Construction (AISC), Manual of Steel Construction, apply vis-a-vis the corresponding provisions of ACI-318.

10.3.3 Clarifications

a) The increased load factor of ACI-318 for earthquake versus wind load is intended to apply in the design of Class B structures of all materials.

b) The load factors of ACI-318 do not apply in designs using materials other than concrete (or unit masonry).

c) The load duration factors for the design of wood members are separate from these provisions relating to load combinations.

d) Non-concurrence of various loads is specified throughout this handbook, and shall be considered in combining loads for the purpose of design.

e) Importance factors (or risk factors) are not used in these criteria, except in conjunction with earthquake and snow loads. However, the designer should keep in mind that the loading criteria given herein provide the minimum level of performance acceptable. Some facilities may require or warrant a higher level of performance. Such requirements usually will be developed before a project reaches the design stage; however, if the requirement has not been identified and the designers believe it is essential, request guidance from NAVFAC Code 15C or NFESC Code 00CE5.

f) For combinations of loads not covered by ACI-318, the provisions which follow relating to load combinations for Class C structures apply.

10.4 Class C Structures. The categories of "Basic Loads" and "Loads of Infrequent Occurrence" are defined for various types of structures in the several topical design manuals or military handbooks, as applicable. Combine as required for specific applications being considered. Where specific categorization is not presented in the topical design manuals or military handbook, the following general criteria apply:

a) Dead load, live load, and impact are basic loads.

b) Wind, earthquake, thermal forces, forces due to shrinkage, forces due to differential settlement, and unbalanced forces due to local failures (such as guy breakage), are loads of infrequent occurrence.

10.4.1 Adjustment of Load Factors and Allowable Stresses. Except where specifically indicated otherwise in the topical design manuals or military handbooks, the following apply:

a) For combinations involving basic loads only, use the basic allowable stresses (or load factors).

b) For combinations involving basic loads, plus one load of infrequent occurrence, increase allowable stresses by 1/3, or multiply overall load factor by 0.75. In no case shall the overall factor be less than 1.10, i.e., a factor of safety of 10 percent based on ultimate strength.

c) For combinations involving basic loads, plus two loads of infrequent occurrence, increase allowable stresses by 40 percent or multiply overall load factor by 0.70. In no case shall the overall factor be less than 1.10, i.e., a factor of safety of 10 percent based on ultimate strength.

d) For combinations involving basic loads, plus three or more loads of infrequent occurrence, design for an overall load factor of 1.10, i.e., a factor of safety of 10 percent based on ultimate strength.

e) Apply factors in calculating ultimate strength (for concrete members).

10.4.2 Miscellaneous Provisions

a) The load duration factors for the design of wood members are separate from these provisions relating to load combinations.

b) Non-concurrence of various loads is specified variously in this design manual and shall be considered in combining loads for purposes of design.

c) For information on importance factors, refer to par. 10.3.3 e).

d) The following loads are considered as of "Infrequent Occurrence."

1) Impacts of minor missiles (for example, small arms ranges and shedding of turbine blade in jet engine test cell).

2) Explosion of engine or other components during testing.

Section 11: DEFLECTION LIMITATIONS

11.1 General. The provisions of the several referenced design standards apply.

11.2 Special Criteria for Allowable Deflection of Elevator and Escalator Beams and Supports. Allowable deflections under static loads (which shall include the static equivalent of the dynamic loads) shall not exceed the following:

11.2.1 Overhead Machine Beams of Alternating-Current Installations. For overhead machine beams of alternating-current installations, and for direct-current installations where car speeds exceed 150 fpm [0.762 m/s] - 1/2000 of the span.

11.2.2 Overhead Machine Beams of Direct-Current Installations. For overhead machine beams of direct-current installations where car speeds are 150 fpm [0.762 m/s] or less - 1/1666 of the span.

11.2.3 Overhead Beams Supporting Machine Beams. For overhead beams supporting machine beams - 1/1666 of the span.

11.2.4 Overhead Sheave Beams. For overhead sheave beams - 1/1666 of the span.

11.3 Machinery Supports (Other Than Elevators and Escalators). Design the beams or girders supporting machines so that the maximum deflection will not exceed 1/500 of the span (impact included), with the span taken as the distance, center-to-center, of the columns and the ends considered as supported without restraint. For criteria regarding deflection limits on supports for centerline guides of turbine generators, refer to par. 6.4.

REFERENCES

NOTE: THE FOLLOWING REFERENCED DOCUMENTS FORM A PART OF THIS HANDBOOK TO THE EXTENT SPECIFIED HEREIN. USERS OF THIS HANDBOOK SHOULD REFER TO THE LATEST REVISIONS OF CITED DOCUMENTS UNLESS OTHERWISE DIRECTED.

FEDERAL/MILITARY SPECIFICATIONS, STANDARDS, BULLETINS, HANDBOOKS, AND NAVFAC GUIDE SPECIFICATIONS:

Unless otherwise indicated, copies are available from the Naval Publishing and Printing Service Office (NPPSO), Standardization Document Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

HANDBOOKS

MIL-HDBK-1002/1 Structural Engineering General Requirements.

MIL-HDBK-1002/3 Steel Structures.

MIL-HDBK-1025/1 Piers and Wharves.

MIL-HDBK-1025/4 Seawalls, Bulkheads, and Quaywalls.

MIL-HDBK-1025/6 General Criteria for Waterfront Construction.

NAVFAC DESIGN MANUALS:

DM-7.01 Soil Mechanics.

DM-7.02 Foundations and Earth Structures.

DM-7.03 Soil Dynamics, Deep Stabilization, and Special Geotechnical Construction.

DM-26 Series Harbor and Coastal Facilities.

DM-38.01 Weight-Handling Equipment.

OTHER GOVERNMENT DOCUMENTS AND PUBLICATIONS:

NAVFAC P-355 Seismic Design for Buildings.

NAVFAC P-355.1 Seismic Design Guidelines for Essential Buildings.

NAVFAC P-397 Structures to Resist the Effects of Accidental Explosions.

(Unless otherwise indicated, copies are available from Naval Publications and Forms Center, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

TM 5-809-1 Load Assumptions for Buildings

(Unless otherwise indicated, copies are available from U.S. Army Publications Distribution Center, 1655 Woodson Road, St. Louis, MO 63114.)

NON-GOVERNMENT PUBLICATIONS:

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS (AASHTO)

HB-13 Standard Specifications for Highway Bridges.

(Unless otherwise indicated, copies are available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol Street, N.W., Washington, DC 20001.)

AMERICAN CONCRETE INSTITUTE (ACI)

ACI-318 Building Code Requirements for Reinforced Concrete.

(Unless otherwise indicated, copies are available from American Concrete Institute (ACI), 22400 W. Seven Mile Road, Box 19150, Redford Station, Detroit, MI 48219.)

AMERICAN INSTITUTE OF STEEL CONSTRUCTION (AISC)

AISC Manual of Steel Construction.

(Unless otherwise indicated, copies are available from American Institute of Steel Construction (AISC), 1 East Wacker Drive, Suite 3100, Chicago, IL 60601.)

AMERICAN RAILWAY ENGINEERING ASSOCIATION (AREA)

AREA Manual for Railway Engineering.

(Unless otherwise indicated, copies are available from American Railway Engineering Association (AREA), 50 F Street, N.W., Suite 7702, Washington, DC 20001.)

AMERICAN SOCIETY OF CIVIL ENGINEERS (ASCE)

Wind-Induced Vibrations in Antenna Members.

(Unless otherwise indicated, copies are available from American Society of Civil Engineers (ASCE), 345 East 47th Street, New York, NY 10017.)

BUILDING SEISMIC SAFETY COUNCIL (BSSC)

FEMA 178 NEHRP Handbook for the Seismic Evaluation of Existing Buildings.

(Unless otherwise indicated, copies are available from Building Seismic Safety Council (BSSC), 1201 L Street, N.W., Suite 400, Washington, DC 20005.)

INTERNATIONAL CONFERENCE OF BUILDING OFFICIALS (ICBO)

Uniform Building Code

(Unless otherwise indicated, subscriptions are available from International Conference of Building Officials, 5360 S. Workman Mill Road, Whittier, CA 90601.)

American Civil Engineering Practice, Volume II, R. W. Abbett, John Wiley and Sons, Inc., New York, NY 10016.

Structural Dynamics, Mario Paz, Van Nostrand Reinhold, New York, NY.

Dynamics of Ice Forces on Piers and Piles, Canadian Journal of Civil Engineering, Volume 3, pp. 305-341.

Mark's Standard Handbook for Mechanical Engineers, Avallona and Baumeister, McGraw-Hill Book Co., New York, NY, 9th Ed., 1987.

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